BBC SCIENCE • TECHNOLOGY • FUTURE

FOCUS

Issue 239 March 2012 £3.95

Smartphones of the future revealed

MYTHICAL CREATURES: WHY THE SEARCH SHOULD GO ON

LIZ BONNIN ON SUPER SMART ANIMALS

How can I avoid the 3pm slump?

PLUS **30** more science questions answered

Unravelling the FABRIC of the UNIVERSE

What the tiniest details tell us about the nature of reality

Master your emotions

Tips and tactics from the world of neuroscience

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Science of seduction

The chemical attraction of perfume and other sexy scents

The digital home

On test: the kit you need to stream music and video

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THE TOP20

Choosing a home cinema system is a potential minefield that must be negotiated with great care or safely avoided by letting experts guide you. If you want to end up with a system that, as a minimum, meets your expectations in terms of picture and sound quality, reading magazine product reviews and choosing the recommendations, five-star favourites or best buys can only ever be part of the answer at best. Looking for the cheapest price and having a system delivered to your door, even with a 'knowledgeable' friend to help set it up, is a well-trodden path to disappointment.

There is a bewildering choice of components on the market today and also different ways in which components can be installed and connected together. Which sort of visual system do you go for? Projector and screen, or plasma, LCD or LED TV? 3D or non-3D? Full 1080p capability is now the only sensible choice but the appropriate source components, such as a Blu-ray player, need to be part of the equation. The sound performance of a system is also hugely important, even more so if you will be listening to music, or music DVD's, through the same system. If so, you need an amp that approaches the performance of a decent 2-channel hi-fi amp, which is not that easy to find. Having an amp with the right inputs for the best connectivity is essential but you will also need to decide on a 5.1 or 7.1 speaker system, passive or active sub and, crucially, where they will be sited for the best results. In short, it's complicated and very fertile ground for getting it wrong.

ACHIEVING POTENTIAL

To select a system, you could choose a collection of 'Best Buy' components in the hope that they will be a great combination. Maybe, but probably not. You could buy a pre-packaged all-in-one system from one manufacturer. This is almost certainly not the best route either as you will miss out on enormous potential. From informal surveys conducted, it appears highly likely that **the majority of home cinema systems selected and installed on a DIY basis (that is without professional input) are performing at way below their optimum level.** To compound matters, most are also ill-matched to the room in which they are installed and are, in reality, the wrong system. Without considerable knowledge or experience, high quality home cinema is not a suitable DIY activity. Our aim must be to buy a home cinema system that will provide an excellent picture quality plus an audio delivery that will match, or even better, the commercial cinema experience. It must be exciting, reliable and deliver true value for money.

WHAT AND WHERE TO BUY

To ensure a home cinema system is right for you, where do you start? Here's an important tip ...**don't** start with **WHAT**, start with **WHERE**. There's only one way to give yourself the best chance of getting it right first time, and that's through a specialist AV dealer. It's possible you have preconceived ideas that put you off visiting one. Although you would welcome the advice and guidance, you don't know the technical jargon. You don't want to be talked down to. Your friend has said they only sell expensive gear and they're not interested if you don't have a big budget. They're expensive. These are just myths.

Most specialist AV dealers are running their business because, above all, home cinema is their hobby. They spend a large portion of their time comparing systems to get the best possible results. They know the component combinations which don't gel together and, conversely, they know the combinations which give the best performance within a given price range. Very importantly, they know how to get a system working to its optimum. But they all also know the system must suit **you**.

> "...Our aim must be to buy a home cinema system that will provide an excellent picture quality plus an audio delivery that will match, or even better, the commercial cinema experience."

So good you'll believe you're there!

GUIDE

TO BUYING HOME A CINEMA SYSTEM

BUYING OR BEING SOLD TO?

There are dealers around, web based or otherwise, who will sell you anything you are willing to pay for. They may be a bit cheaper but that's all they offer. Now there's a carefully selected group of long-established specialist dealers who are totally committed to putting the customer first. Their idea of 'selling' is to discuss your requirements, offer their advice, give you the best options, then play the systems for you and allow you to be the judge. You'll probably be surprised and, almost certainly, relieved to discover how easy it is to see and hear the differences between components and between systems. You'll be able to make a clear and informed decision about what to buy.

The story doesn't end there. These shops won't abandon you once you've put your hand in your pocket. They won't leave you to set up the system you've selected as best you can. They'll install it in your home, make sure it performs to its best, and ensure you're entirely happy with the way it works. Why? Because a high proportion of these dealers' custom comes through people who have bought from them before, either directly or by recommendation. It's vital to them to get it right for you.

GETTING THE BEST DEAL

Unless you've got money to burn, you'll be living with your new system for years. Most of these dealers offer much longer equipment guarantees than provided by the manufacturer, a very worthwhile benefit, but it also makes it in the dealer's interest to ensure high build quality and reliability. Maybe you could save a few pounds by buying piecemeal but you'll lose out on the overall package. As far as the dealers are concerned, they believe that taking care of their customers properly is a far better way of doing business than just handing over boxes.

LISTED BELOW ARE 20 OF THE BEST AV SHOPS IN THE COUNTRY

They have been selected because they are known to do an excellent job in guiding customers towards home cinema systems that will provide years of superlative performance and total satisfaction.

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www.castlesoundvision.com

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www.musicmatters.co.uk

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CEDIA® BADA

The majority of the above dealers are members of one or both of the major trade organisations, BADA or CEDIA.

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SERVICE	★★★★★
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Welcome

March 2012

SUBSCRIBE AND
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Already a subscriber? There's an exclusive interview with Dame Jocelyn Bell Burnell for you on p34

The Ancient Greek philosophers spent a great deal of time thinking about things, and one of the things they pondered most was measurement. It led to a famous paradox. To travel a particular distance, from A to B, you first need to reach halfway (let's call it C). But to reach C, you first have to get halfway to C. And so on... and on, forever. You'll have to travel an infinite number of short distances before you can reach your destination. In other words, you never actually arrive at B.

It's patently not true. If it were, I'd never make it to work every morning. But what does modern science have to say about the smallest possible scale – the stitches in the fabric of the Universe itself? Robert Matthews investigates on page 37.

There's more food for thought on page 48, where BBC science presenter Liz Bonnin considers animal intelligence. Are animals smarter than us? Might they feel emotions? Both are questions Liz set out to answer for her new series, *Super Smart Animals*, and she comes to some fascinating conclusions.

It's human emotions that get the scientific treatment on page 66, where we catch up with psychologist Richard Davidson. In writing his new book, Davidson used the latest brain science to find out what makes us tick.

Our emotions rule on Valentine's Day, of course, and synonymous with 14 February is that most glamorous of gifts – perfume. There's more science behind it than you might think – turn to page 46 for some facts about the smelly stuff.

If you'd rather receive some tech from a loved one, we have watches on page 90 and network storage devices (dull name, useful gadgets) on page 92. We also take a look at future smartphones on page 55.

Finally, if you're not already a member, why not sign up to Magazine Insiders? It's our online survey tool and you'll find it at www.magazineinsiders.com. We'll simply send you the occasional poll to ask you what you think of the magazine.

Until next issue,

Graham

Focus iPad edition

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What I've found out this month

- Around 7,000 years ago, a 25m-high tsunami hit the Shetland Isles (p65)
- You can buy a watch with an eink display like the Kindle's (p90)
- Woolly mammoth DNA could help current conservation efforts (p70)

Experts

Sarah Castor-Perry
Sarah studied zoology at Cambridge, and she produces and presents *The Naked Scientists* podcast. On p46, she writes about the science behind perfume, sexy scents and chemical attraction.

Professor Bill McGuire
Professor McGuire considers 'worrying about the future of the planet' as a hobby. On p61, he looks at whether climate change is about to prompt an angry reaction from planet Earth.

Liz Bonnin
Before presenting *Bang Goes The Theory*, Liz did a masters degree in animal biology at the Zoological Society of London. On p48, she reveals how animal intelligence can rival and even surpass our own.

Dr Henry Nicholls
Henry has a PhD in evolutionary ecology and is the author of *The Way of the Panda* and *Lonesome George* about the last tortoise on Pinta Island. On p68, he tackles conservation genetics.

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> **Professor Bill McGuire, 'Climate change's nasty secret', p63**

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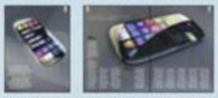

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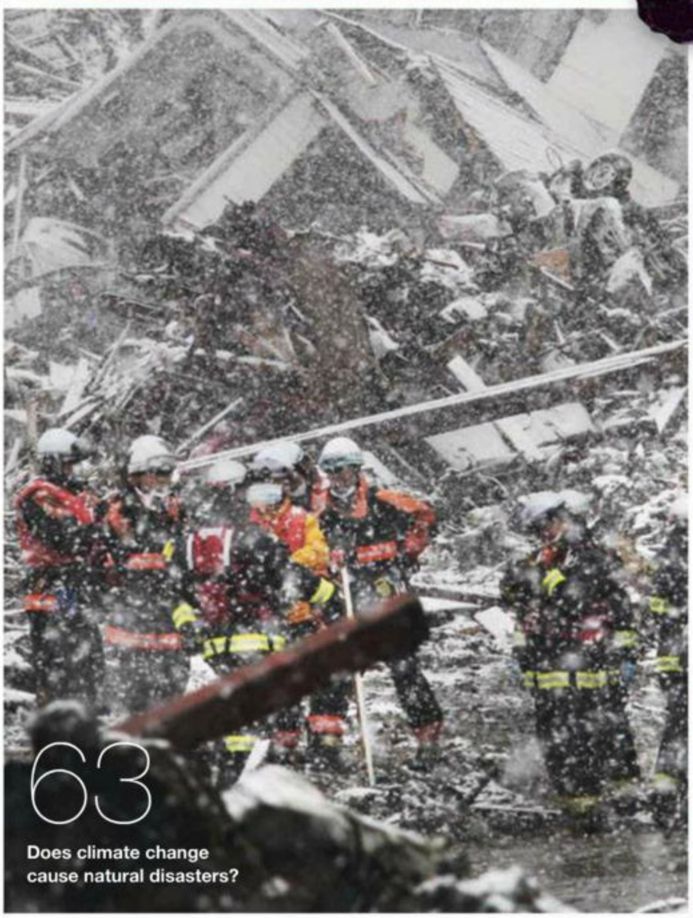

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Does climate change cause natural disasters?

DANIEL ALLISON, PAULWESTON.INFO, BBC, STUDIO4PHOTO.CO.UK, MAGICTORCH, PRESS ASSOCIATION

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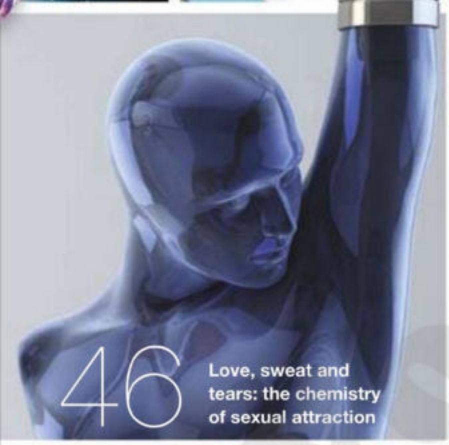

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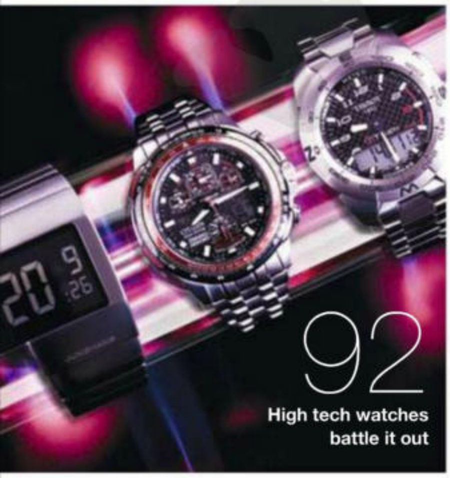

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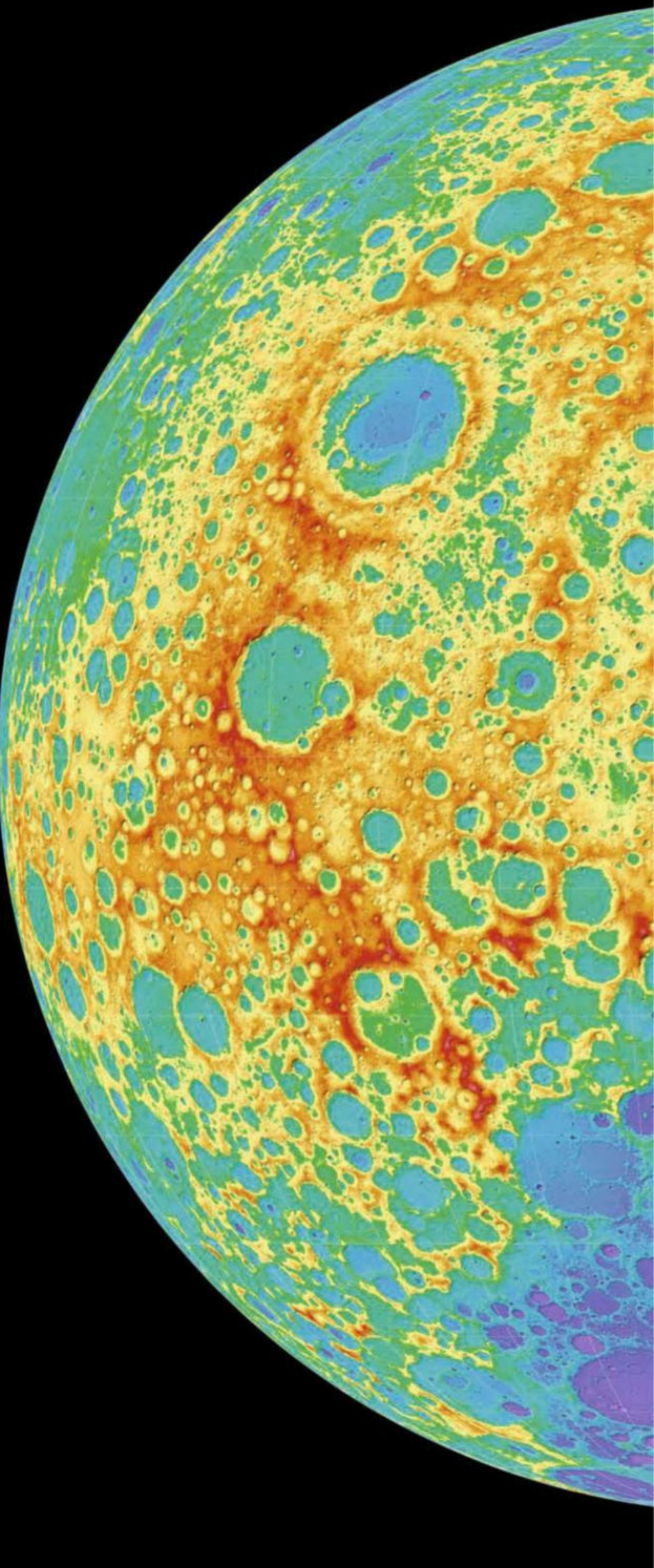
MegaPixel

Mapping the Moon

The Moon has been photographed extensively ever since the first (Soviet) probe paid a visit in 1959. Now, data from NASA's Lunar Reconnaissance Orbiter has been used to create the most detailed topographic map of the lunar surface to date. Colours reveal the heights of different features, with white representing the highest peaks and purple the lowest points.

The LRO's wide-angle camera takes images of a 70km-wide (43 mile) swathe as it orbits 50km (31miles) above the Moon's surface. As each orbit is just 30km (18 miles) apart, it means there's considerable overlap between images. And because the overlapping images are taken from slightly different angles, they can be used to calculate the heights and depths of the mountains and craters on the Moon's surface.



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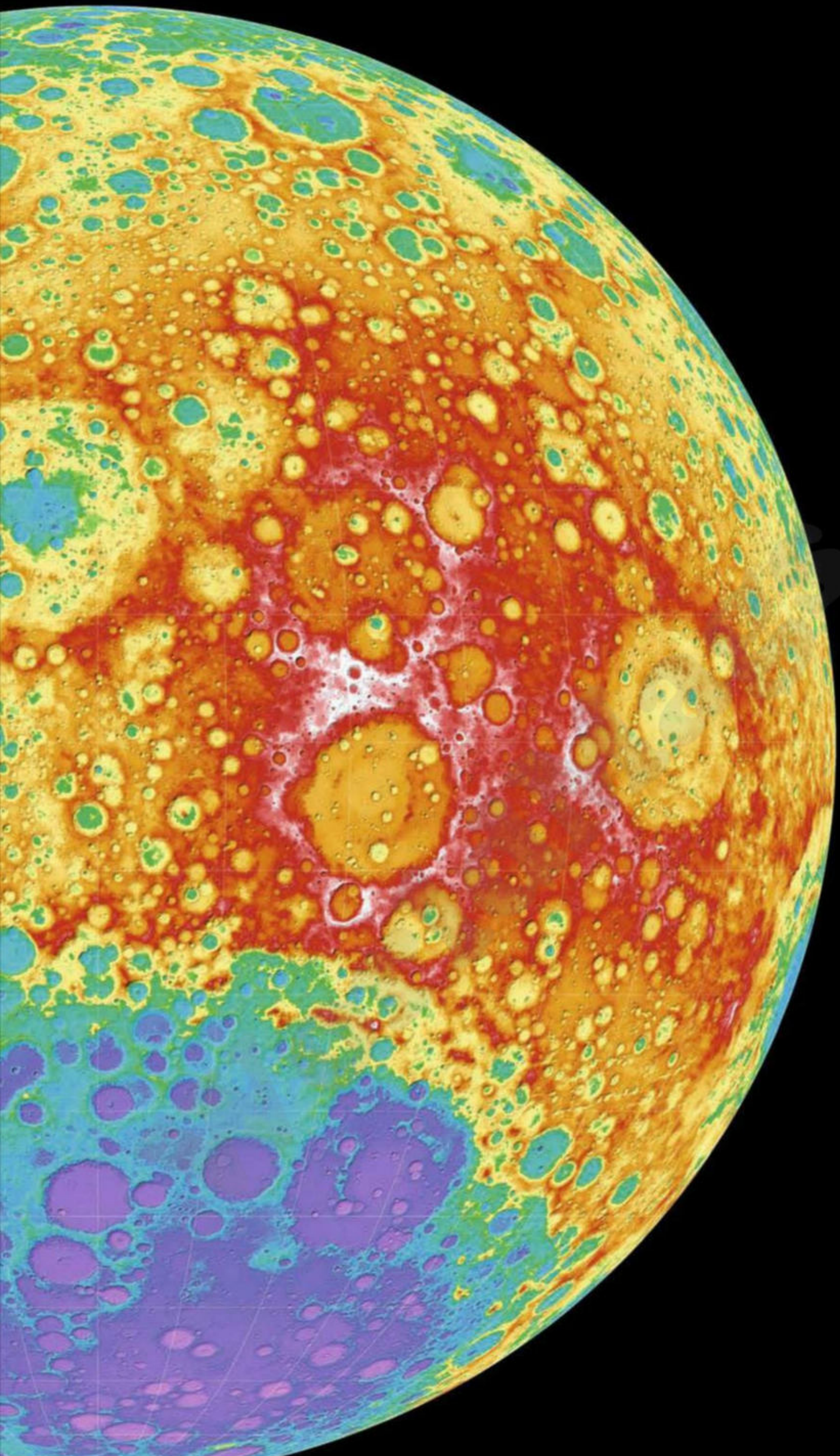
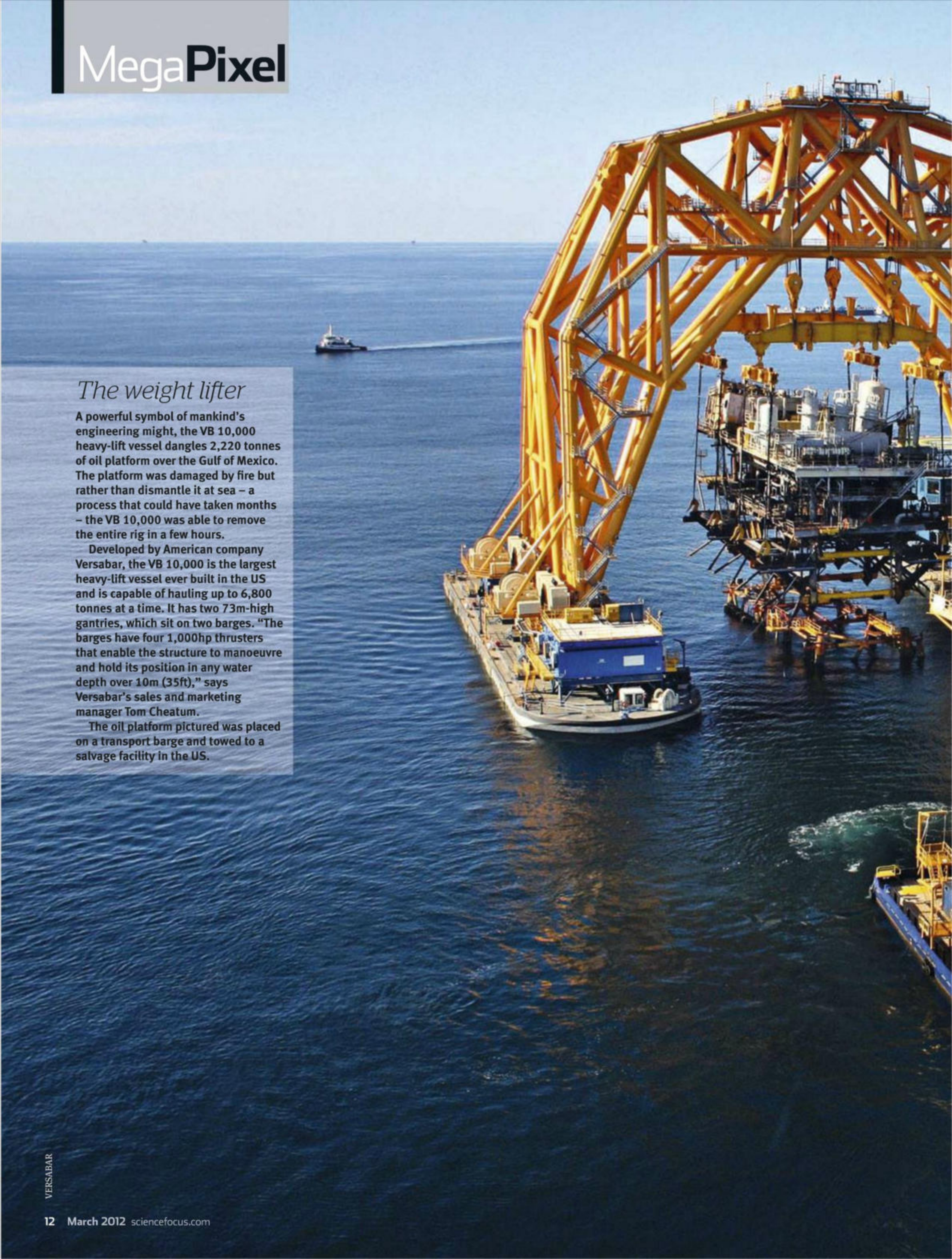




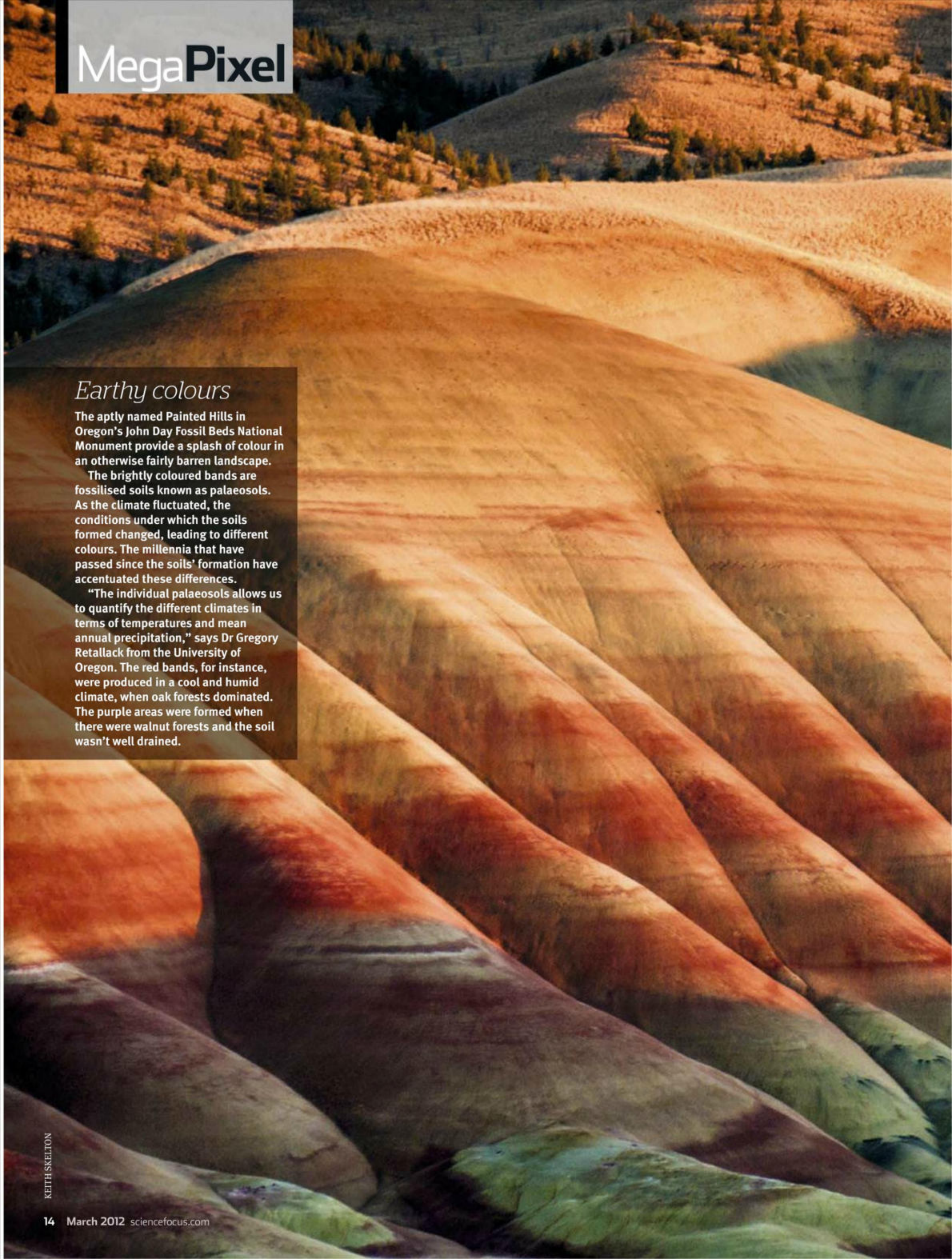
The weight lifter

A powerful symbol of mankind's engineering might, the VB 10,000 heavy-lift vessel dangles 2,220 tonnes of oil platform over the Gulf of Mexico. The platform was damaged by fire but rather than dismantle it at sea – a process that could have taken months – the VB 10,000 was able to remove the entire rig in a few hours.

Developed by American company Versabar, the VB 10,000 is the largest heavy-lift vessel ever built in the US and is capable of hauling up to 6,800 tonnes at a time. It has two 73m-high gantries, which sit on two barges. "The barges have four 1,000hp thrusters that enable the structure to manoeuvre and hold its position in any water depth over 10m (35ft)," says Versabar's sales and marketing manager Tom Cheatum.

The oil platform pictured was placed on a transport barge and towed to a salvage facility in the US.

VERSABAR



Earthy colours

The aptly named Painted Hills in Oregon's John Day Fossil Beds National Monument provide a splash of colour in an otherwise fairly barren landscape.

The brightly coloured bands are fossilised soils known as palaeosols. As the climate fluctuated, the conditions under which the soils formed changed, leading to different colours. The millennia that have passed since the soils' formation have accentuated these differences.

"The individual palaeosols allows us to quantify the different climates in terms of temperatures and mean annual precipitation," says Dr Gregory Retallack from the University of Oregon. The red bands, for instance, were produced in a cool and humid climate, when oak forests dominated. The purple areas were formed when there were walnut forests and the soil wasn't well drained.

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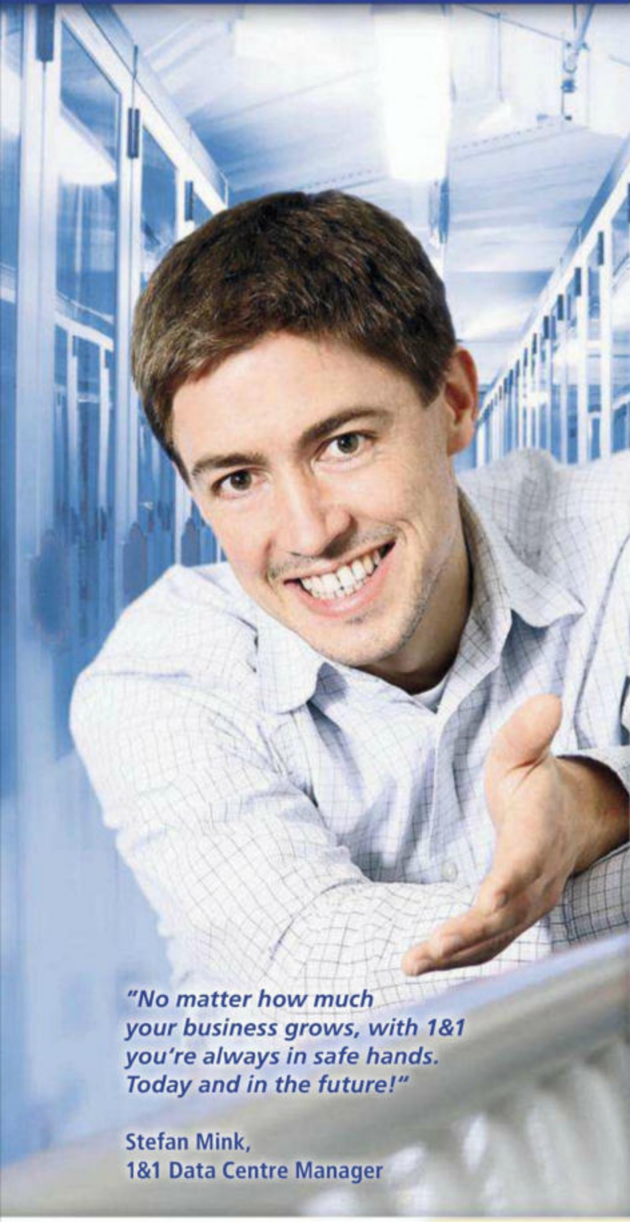

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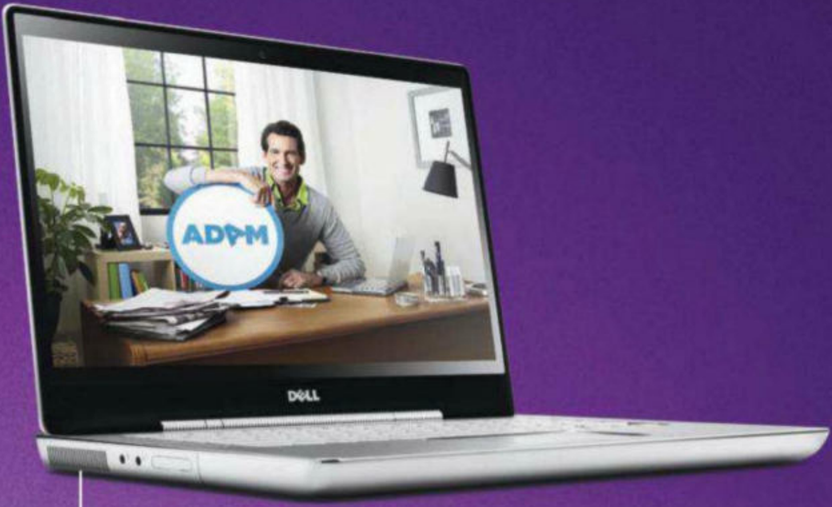

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Need to know

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New light cast on **black holes**

An imminent collision with our closest black hole should reveal their inner workings

Astronomers have spotted a giant gas cloud that is destined to be swallowed up by the black hole at the centre of our Galaxy. The event presents an unprecedented opportunity to see how the matter-sucking void swallows its prey.

While black holes are common, it's the proximity of the Milky Way's Sagittarius A*, a mere 26,000 light-years from Earth, that makes the gas cloud's demise so significant for astronomers.

"We know that black holes get fed all over the Universe but it's a riddle how things are actually consumed," says Dr Stefan Gillessen, an astrophysicist at the Max Planck Institute for Extraterrestrial Physics in Germany. Gillessen led a study that predicts the gas cloud's path. "Now we have a gas cloud heading directly for the only black hole close enough for us to observe. It's a unique chance to see what happens."

After plotting its orbit using the European Southern Observatory's Very Large Telescope in Chile for almost a decade, Gillessen and his international team say the dusty gas cloud, composed mainly of helium and hydrogen, will pass within 40 billion kilometres (25 billion miles) of the black hole during the summer of 2013. That's close enough to encounter the hole's 'accretion zone', a gas disc that surrounds it.

The cloud is already being distorted. With a mass around four million times that of the Sun, Sagittarius A* exerts an immense gravitational pull that nothing can escape if it ventures too close. Eventually half the gas cloud is expected to be consumed by the hole, with the rest flung away.

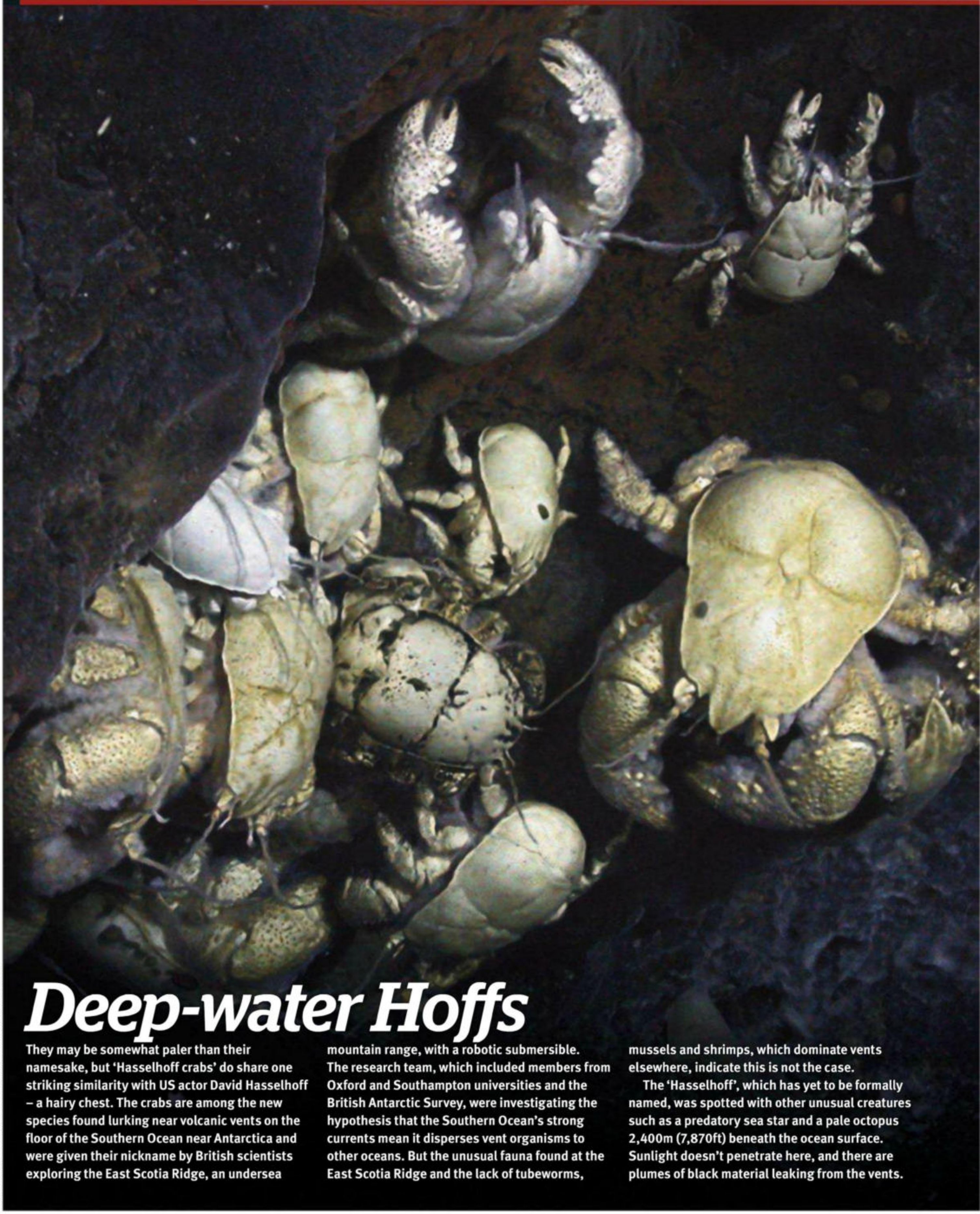
As the gas speeds up and hits hotter, denser gas in the accretion zone it will heat up to several million Kelvin, hot enough to produce intense X-ray emissions. Later, gas raining down into the hole may create giant radiation flares – huge releases of energy – that it will be possible to observe in several wavelengths.

What the cloud can teach us

The fate of the gas cloud heading for Sagittarius A* should reveal something of the extreme conditions around the black hole. It is when the gas encounters the hole's accretion zone in 2013 that things will get even more interesting.

"It will be really fascinating to see how much radiation is produced because that will tell us about the density of the gas around the black hole," explains astrophysicist Dr Stefan Gillessen. "As we watch the cloud breaking up over the next few years we can also make observations about the gravitational forces in the area immediately surrounding the black hole."

ESO



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Deep-water Hoffs

They may be somewhat paler than their namesake, but 'Hasselhoff crabs' do share one striking similarity with US actor David Hasselhoff – a hairy chest. The crabs are among the new species found lurking near volcanic vents on the floor of the Southern Ocean near Antarctica and were given their nickname by British scientists exploring the East Scotia Ridge, an undersea mountain range, with a robotic submersible. The research team, which included members from Oxford and Southampton universities and the British Antarctic Survey, were investigating the hypothesis that the Southern Ocean's strong currents mean it disperses vent organisms to other oceans. But the unusual fauna found at the East Scotia Ridge and the lack of tubeworms, mussels and shrimps, which dominate vents elsewhere, indicate this is not the case.

The 'Hasselhoff', which has yet to be formally named, was spotted with other unusual creatures such as a predatory sea star and a pale octopus 2,400m (7,870ft) beneath the ocean surface. Sunlight doesn't penetrate here, and there are plumes of black material leaking from the vents.

MONTH IN NUMBERS

80%

of the smallest spiders' body cavities are filled by brains, the Smithsonian Institute in Panama found.

£247,000

is how much Apollo 13 commander Jim Lovell sold a mission checklist for. NASA questions his right to sell.

20 tonnes

of dead herring were washed up on a beach in north Norway. Biologists are still trying to work out why.

13,600

years is the age of the second oldest human genetic disease mutation yet discovered. It is a vitamin B12 deficiency.

Nanoantennas are made from gold just 40 nanometres thick

***Nanoantennas** could revolutionise communication*

Tiny structures bend light in ways thought impossible

Structures made up of just a few hundred atoms, and that bend light in ways previously thought impossible, could lead to advances in computing, microscopy and telecommunication.

Until now, Snell's law has implied that when light passes from one material to another, there is a limit to the extent to which it can be refracted, or bent. Nanoantennas, v-shaped structures made from gold that are just 40 nanometres – or billionths of a metre – wide, can break this law.

Research published by Harvard physicists in October 2011 shows that at one wavelength of light, a group of nanoantennas can dramatically change its phase – the relative positions of the peaks and troughs of light waves. In doing so, the way it bends can be manipulated.

Now researchers at Purdue University in Indiana have shown that nanomaterials can achieve their light-bending feats across a wide range of near-infrared light. "It's important because all optical communication occurs at this wavelength," says Professor Vladimir Shalaev at Purdue. "Our arrays are also extremely thin, which is important for miniaturisation of optical devices."

This new ability to shape and steer the beam would prove particularly useful at the point where the data is encoded and decoded in optical communication systems.

Nanoantennas have free electrons that couple extremely efficiently with light. "That coupling changes the phase of the light," says Shalaev. "The degree to which the phase changes depends on the shape and arrangement of the antenna, so by designing these arrays we can bend the light in any direction."

If these light-bending effects can be demonstrated at other wavelengths, nanoantennas could be used to steer and shape laser beams for the military and communications and to provide powerful lenses for microscopes.

GOOD NEWS

The fine hairs on our bodies allow us to feel parasitic bugs as well as creating a barrier against them, University of Sheffield research shows.

In future your shirts may be able to clean themselves. Chinese scientists have developed a new coating for cotton which, when exposed to light, emits oppositely charged particles – electrons and 'electron holes'. These encourage oxidation reactions, breaking down organic material such as dirt.

Mathematics may soon help you avoid a car crash. An algorithm – a computational procedure – which can more accurately predict when a driver is likely to ignore a red traffic light than its predecessors has been created at Massachusetts Institute of Technology (MIT) in the US.

BAD NEWS

Eating lots of sugary food could make you look older. More than 500 volunteers had their blood glucose level measured after a meal. Sixty assessors also estimated their age from photos. Those with higher blood glucose levels after the meal tended to be rated as older than those whose glucose level was lower.

The Epstein-Barr virus, which is responsible for glandular fever, also causes the brain damage seen in multiple sclerosis. An international research team found that the virus releases a form of genetic material, RNA, and this causes inflammation that can damage nerve cells.

A poor diet in pregnancy can raise a baby's risk of diabetes by reducing its ability to store fat, research at Cambridge and Leicester universities suggests.

INSIGHT

Exercise pill

What's that? A pill I can pop instead of going to the gym?
Not quite. It's a pill you may be able to take in the future that would replicate some of the effects of a work-out. It'll help treat conditions such as obesity and diabetes.

What's in this pill then?
A hormone called irisin. It's produced in the body in response to exercise.

What does irisin do exactly?
It causes a gene to be switched on that works on white fat stored under the skin. This fat stores calories and contributes to obesity, but a rise in irisin levels causes it to be converted into 'good' brown fat, which acts like the body's furnace, consuming calories and generating heat. Mice given irisin lost a few grammes in the first days of treatment. It also appears to improve control over glucose levels in the body.

So why isn't irisin a replacement for a trip to the gym?
It doesn't appear to make your muscles any stronger.

When will irisin be available?
It's early days yet, but Bruce Spiegelman, head of the team at the Dana-Farber Cancer Institute in Boston who discovered the hormone, has already set up a company called Ember Therapeutics to develop brown fat-related treatments, including irisin. He's hoping to run clinical trials within two years.

For now, there is no pill-shaped substitute for hard work at the gym

ROUND UP

This month's top science stories from around the globe

SPACE

Smallest exoplanets yet

The three smallest planets yet to be discovered orbiting a star other than our own Sun have been detected, using NASA's planet-hunting Kepler space telescope. The planets are 0.78, 0.73 and 0.57 times the radius of Earth, making the smallest barely larger than Mars. Like Earth, they are thought to be rocky planets. Unfortunately, they orbit so close to their star, a red dwarf named KOI-961, that they're certain to be somewhat frazzled – liquid water on their surfaces appears to be out of the question.

GEOLOGY

Moon rock found on Earth

A mineral previously known only on the Moon has been found on Earth. Tranquillityite has been confirmed at six sites in Western Australia by scientists from Curtin University in Perth and other Australian universities. Flecks of the mineral from rock samples scattered electrons in a distinctive pattern that matched that of lunar samples. Tranquillityite's presence will be quite handy – measuring its proportions of radioactive isotopes will reveal the age of rocks in which it is found.

NEUROLOGY

Inside drinkers' brains

Some people may be more prone to heavy drinking because alcohol prompts a bigger reaction in their brains. Brain scans of heavy drinkers carried out at the University of California, San Francisco, revealed higher levels of psychoactive chemicals called opioids in 'reward centres' in the brain – the orbital frontal cortex and the nucleus accumbens. This means heavy drinkers will derive more pleasure from each drink. The findings could help in developing new alcohol abuse treatments.

ATMOSPHERIC SCIENCE

Rethink on early atmosphere

New research calls current ideas about Earth's early atmosphere into question. When US scientists set about replicating the production of the mineral zircon on the early Earth, they could only produce a similar substance with high oxygen levels, suggesting the early atmosphere must have been higher in oxygen (bound up in water and CO_2) than was thought. This would have made it less amenable to the emergence of life than the methane- and chlorine-rich atmosphere previously imagined.

WILDLIFE

Hummingbirds fly like bugs

Hummingbirds pull off their aerial antics by flying more like insects than their feathered cousins. Most birds only produce lift in the downward flap – their wings are drawn towards their body on the upstroke. But hummingbirds flip their wings before they flap upwards, creating lift in both directions. Using high-speed X-ray footage of ruby-throated hummingbirds (*Archilochus colubris*), biologists at the University of North Carolina found that the birds twist their wrists before each upstroke.

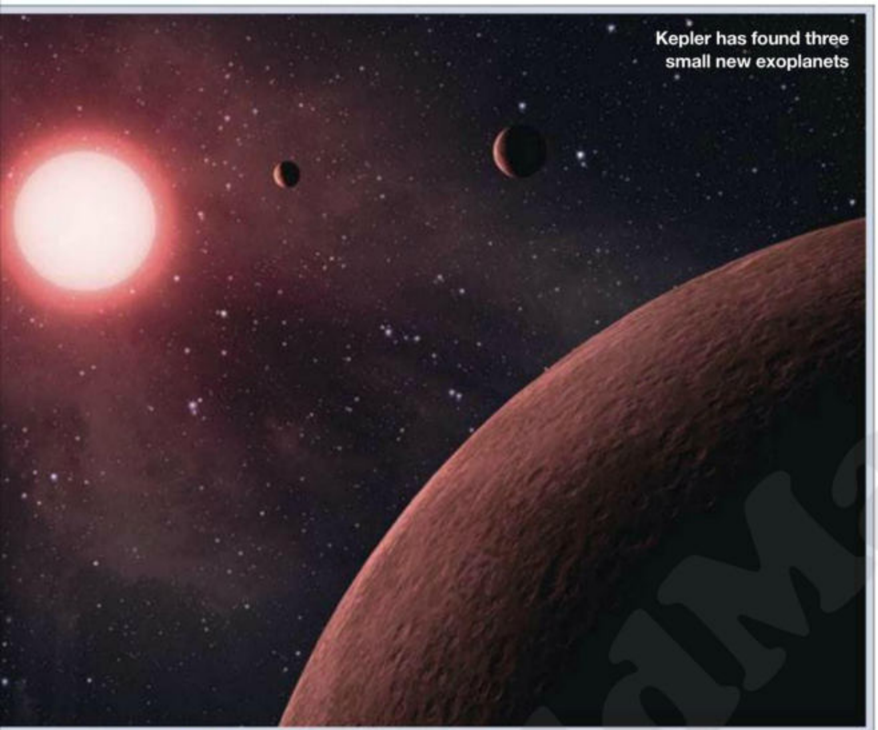
HEALTH

Pollen exposure eases hay fever

It's almost the season of pollen-induced sneezing – and new research from the Netherlands shows that pollen's effects are not equal throughout the spring and summer. Scientists at the Leiden University Medical Centre compared symptoms in over 80 hay fever sufferers with daily pollen counts. Even with the same pollen levels, symptoms were more severe early in the season than later. Exposure to pollen may 'down regulate' the response, possibly through the production of regulatory T cells, the cells which control the immune system.

Bugging out: the hummingbird

NASA/JPL X2, NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY, DAVID L OSBORN, PHOTO RESEARCHERS/FLPA, THINKSTOCK



Kepler has found three small new exoplanets

PALAEONTOLOGY

Sauropods roamed Antarctica

It appears that giant long-necked sauropod dinosaurs lumbered around the Antarctic 60 million years ago. Argentinean palaeontologists have found the remains of part of a sauropod on James Ross Island. It means the plant-eating creatures would have inhabited *all* the world's continents by the end of the Late Cretaceous period. The size and shape of the vertebrae indicate this specimen was a titanosaur – the dominant group within the sauropods at the end of the Cretaceous.

FOOD

Taste is a geographical issue

Whether different foods 'go' together or not depends where you come from. That's the conclusion of research carried out at the University of Cambridge and in the US, in which the ingredients in 56,000 recipes from different continents were analysed to look for patterns in the flavour molecules combined. They found that western chefs tend to combine foods with similar flavour molecules, while Asian chefs avoid such pairings. The research indicates that some odd combinations – chocolate and blue cheese, coffee and garlic – should appeal to Western palates.

RADICAL CLIMATE FIX?

They have a pretty strange name, but it's one worth remembering: Criegee biradicals could help save us from global warming.

The existence of the molecules in the atmosphere was suggested back in the 1950s, but now scientists have been able to isolate them – and have found they react quickly with hydrocarbon pollutants, producing nitrates and sulphates that seed climate-cooling clouds.

In the past, the fact that Criegee biradicals quickly turn into other molecules was a problem. Now, though, British and US scientists at Lawrence Berkeley National Laboratory in California are able to use intense beams of light to sort molecules and find different isomeric species of molecules (with the same atoms, but arranged differently).

Rather than pumping Criegee biradicals into the atmosphere, however, the scientists say their research highlights the need to preserve Earth's natural ecosystems.

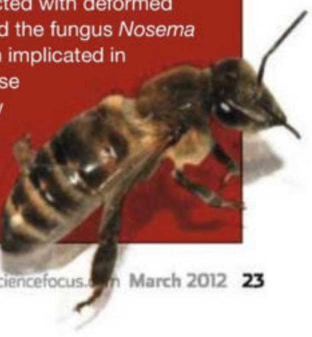
NEWS IN BRIEF

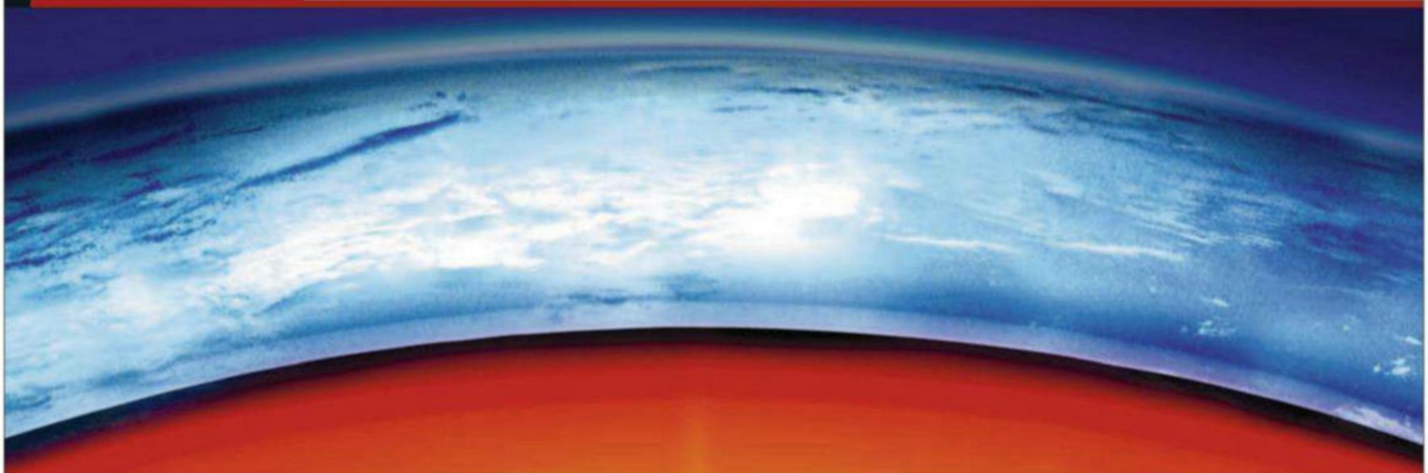
Our ability to form new memories may be controlled by a master gene. Studies have shown that the Npas4 gene is turned on by new experiences, but research at MIT in the US has found that it also switches on several other genes that alter the strength of connections between nerve cells, or neurons, allowing new memories to be formed

Two NASA spacecraft orbiting the Moon will soon start producing a map of its gravity variations. The GRAIL satellites entered lunar orbit in January and, once in sufficiently tight orbit 55km (34 miles) above the surface, will begin making detailed measurements of the Moon's gravity. This data will allow astronomers to deduce the Moon's structure and from that infer how it was formed.

University of Nottingham scientists have been levitating fruit flies using a magnet, to give them a better understanding of the effects of zero gravity. Most biological materials are weakly repelled by a magnetic force; the magnet in Nottingham is so powerful that this 'diamagnetic' effect cancels out gravity. In such conditions the flies walked faster – the same phenomenon that has been observed in flies aboard the International Space Station.

A parasitic fly turns bees into a zombie-like state, leaving their hives at night and being attracted to light. The fly, *Apocephalus borealis*, deposits eggs in the bees' abdomen. Affected hives often contain bees and flies infected with deformed wing virus and the fungus *Nosema ceranae*, both implicated in colony collapse disorder. How the parasite fits into the picture is unclear.





Strange goings on at Earth's core

The intense pressure near the Earth's core generates a rather unexpected change in a key component of the mantle – the rocky layer surrounding the molten outer core. It's a change that could transform our understanding of how the Earth's interior produces the magnetic field that shields us from harmful cosmic rays.

To find out more about how it behaves inside Earth, geophysicists from the US and Japan subjected iron oxide to pressures and temperatures similar to those around the core – up to 2,200°C and 1.4 million times atmospheric pressure. Under such conditions, the compound – a component of ferropericlase, the second most abundant mineral at the lower mantle – changes from being an insulator to a highly conductive metal. Contrary to what was previously thought, this transformation takes place without a change to iron oxide's crystal structure.

"The fact that one mineral has properties that differ so completely depending on its composition and where it is in the Earth is a major discovery," says Dr Ronald Cohen at the Carnegie Institution for Science in Washington DC. Near the Earth's core, the iron oxide atoms and the electrons they contain are squeezed so tightly together that they interact differently, leading to the substance becoming conductive.

"Conductive iron oxide will enhance the electromagnetic interaction between the liquid core and the lower mantle," says Cohen. "Earth's magnetic field is generated in the outer core and the iron oxide will change the way the magnetic field is propagated to the surface."

Astronomical whodunnit solved

Astronomers have discovered the culprits behind a supernova, a stellar explosion, that would have been visible 400 years ago.

A 'remnant' of the event can be seen 160,000 light-years away in the Large Magellanic Cloud and has been photographed by NASA's Hubble Space Telescope. It's an image that has provided astronomers at Louisiana State University in the US with a crucial clue.

It has long been thought that Type 1a supernovae like this could either be caused by a white dwarf star siphoning material from a regular companion star before exploding, or two white dwarfs colliding – the impact obliterating both.

Crucially, when the astronomers searched the centre of the supernova remnant, they found no signs of the regular star that would have remained had the cause been a white dwarf star interacting with a companion. So it seems that two white dwarves collided, leaving nothing behind.

SCIENCE PHOTO LIBRARY, NASA/HUBBLE SPACE TELESCOPE

LOOK BACK

40 YEARS AGO
NASA launches Pioneer 10 to explore the outer Solar System. It carries a plaque describing what we look like and where we are.

30 YEARS AGO
The first fossil of a land mammal found on Antarctica is a marsupial. The continent may have provided a bridge between Australia and South America.

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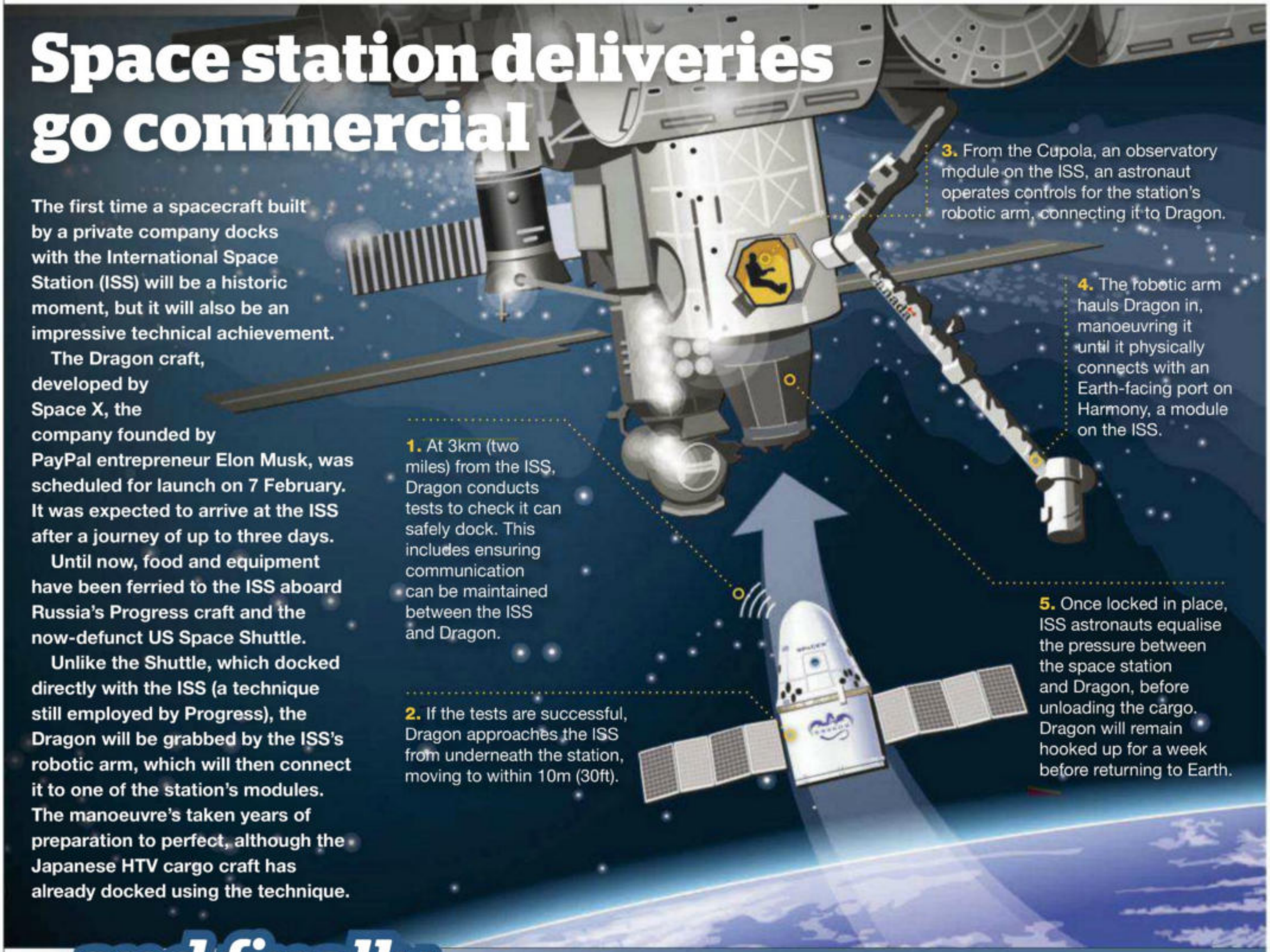
Space station deliveries go commercial

The first time a spacecraft built by a private company docks with the International Space Station (ISS) will be a historic moment, but it will also be an impressive technical achievement.

The Dragon craft, developed by Space X, the company founded by PayPal entrepreneur Elon Musk, was scheduled for launch on 7 February. It was expected to arrive at the ISS after a journey of up to three days.

Until now, food and equipment have been ferried to the ISS aboard Russia's Progress craft and the now-defunct US Space Shuttle.

Unlike the Shuttle, which docked directly with the ISS (a technique still employed by Progress), the Dragon will be grabbed by the ISS's robotic arm, which will then connect it to one of the station's modules. The manoeuvre's taken years of preparation to perfect, although the Japanese HTV cargo craft has already docked using the technique.



1. At 3km (two miles) from the ISS, Dragon conducts tests to check it can safely dock. This includes ensuring communication can be maintained between the ISS and Dragon.

2. If the tests are successful, Dragon approaches the ISS from underneath the station, moving to within 10m (30ft).

3. From the Cupola, an observatory module on the ISS, an astronaut operates controls for the station's robotic arm, connecting it to Dragon.

4. The robotic arm hauls Dragon in, manoeuvring it until it physically connects with an Earth-facing port on Harmony, a module on the ISS.

5. Once locked in place, ISS astronauts equalise the pressure between the space station and Dragon, before unloading the cargo. Dragon will remain hooked up for a week before returning to Earth.

...and finally

Sea snail's lessons

The humble sea snail could teach us a thing or two about learning. Research has shown that certain proteins in their brains are linked with memory and now scientists at the University of Texas have developed a computer model that accurately predicts when their minds are neurochemically primed to remember things. If the results can be applied to humans, it shows that learning sessions that take place at irregular intervals linked to certain protein levels could be more effective than regular studying stints.

Insight into sea snail's brain chemistry could supercharge revision sessions

Hunt for Tatooine is on

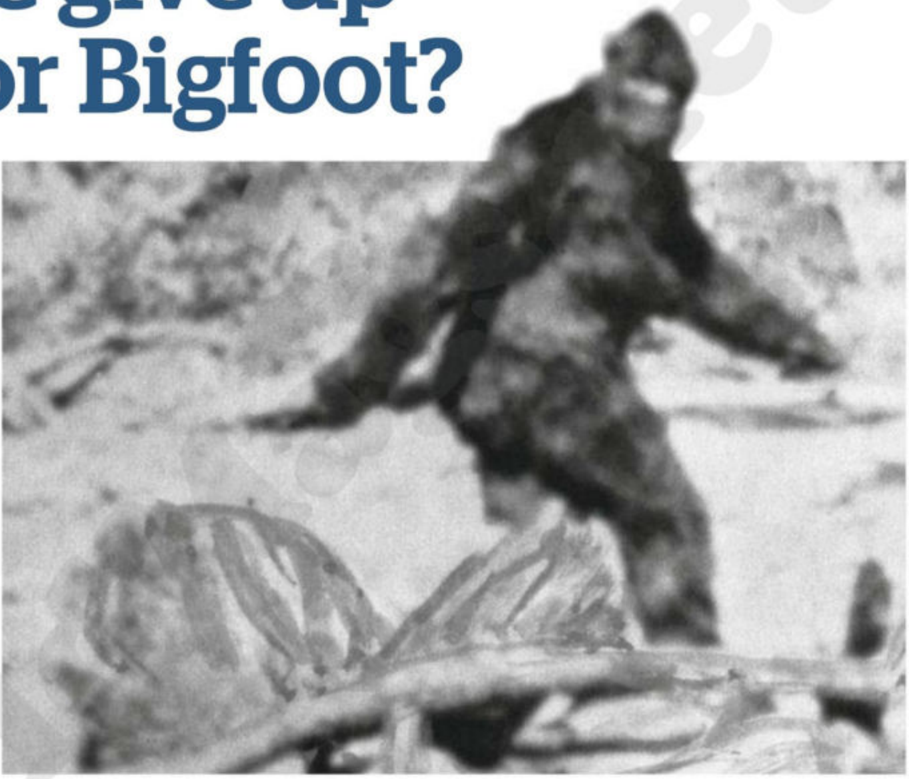
Astronomers have been given guidance on where to look for a habitable planet that orbits a pair of stars, just like Tatooine in the *Star Wars* films. The first real 'circumbinary' planet, Kepler-16b, was discovered last September, but it is a gas giant rather than a terrestrial world. However, University of Texas at Arlington physicists used the Kepler-16 twin sun system as a basis to calculate the distances and conditions, such as the level of greenhouse gases, that would lead to a Tatooine-like world.

CORBIS, R CLAYTON MCKEE, ILLUSTRATION BY PAULWESTON.INFO

Dr Darren Naish is a palaeontologist at the University of Southampton and was formerly on the editorial board of the journal *The Cryptozoology Review*

With Darren Naish

Should we give up looking for Bigfoot?



The news that an infamous 'yeti finger' taken from a Nepalese monastery during the 1950s is from a person, not a new species of giant Himalayan ape, won't surprise many. The notion that it came from a yeti was finally laid to rest by a DNA test at Edinburgh Zoo, which pointed to its human origin. Yet again, evidence thought to demonstrate the existence of the famous mystery animal has failed the test.

Every year we hear how naturalists have trekked into remote areas in search of yetis and other mythical beasts. Given that these searches seem destined to end in failure, are they a waste of time, effort and money? This isn't an easy question to answer, as legendary creatures are not created equal.

Fundamental to this question is whether people who search for such creatures ever meet success. The answer is yes, but it's a yes that must be qualified. The most famous success is the Okapi, a short-necked relative of the giraffe native to tropical central Africa. Known to locals as the Atti, it had been mentioned by explorer Henry Stanley in his 1888 travelogue. It was on the basis of this information that another explorer, Harry Johnston, went in pursuit of it, finding it in 1900. More recently, the Kipunji (a Tanzanian monkey, named in 2006), Giant peccary (named in 2007) and Burmese snub-nosed monkey (named in 2010) were all discovered following investigations of local stories. But the animals concerned are, while interesting, not of the size or monstrous nature expected of cryptozoological superstars like the yeti, Bigfoot or Nessie.

So could new species of large animal still await discovery? Again, the answer is yes. New species are found all the time, and they're not all insects or bacteria. A long-horned relative of cattle, the Saola, amazed zoologists when discovered in southeast Asia in 1992, while two new dolphin and more than 10 new primate species have been named since 2005. But none of these discoveries came after years of rumour and investigation.

If investigations of tales do yield new species, and if new large animals are out there to find, are quests for mythical monsters worthwhile or not? Here's where we have to make a judgement call. Some mystery animals appear unlikely in the first place – they're reported from well-studied areas, like North America or the UK, have been the subject of numerous discovery attempts and remain unrepresented by good evidence. There's no reason to take their existence seriously.

> *"Other mystery beasts seem plausible in size and lifestyle"*

But other mystery beasts come from remote regions and seem plausible in size and lifestyle. One example is the orang pendek, a bipedal ape reported from Sumatra. Of the few expeditions that have searched for it, all have resulted in sightings, or even in the recovery of tracks or hairs. We need bones or a dead body before the creature can be declared discovered, but the point is that its existence appears credible.

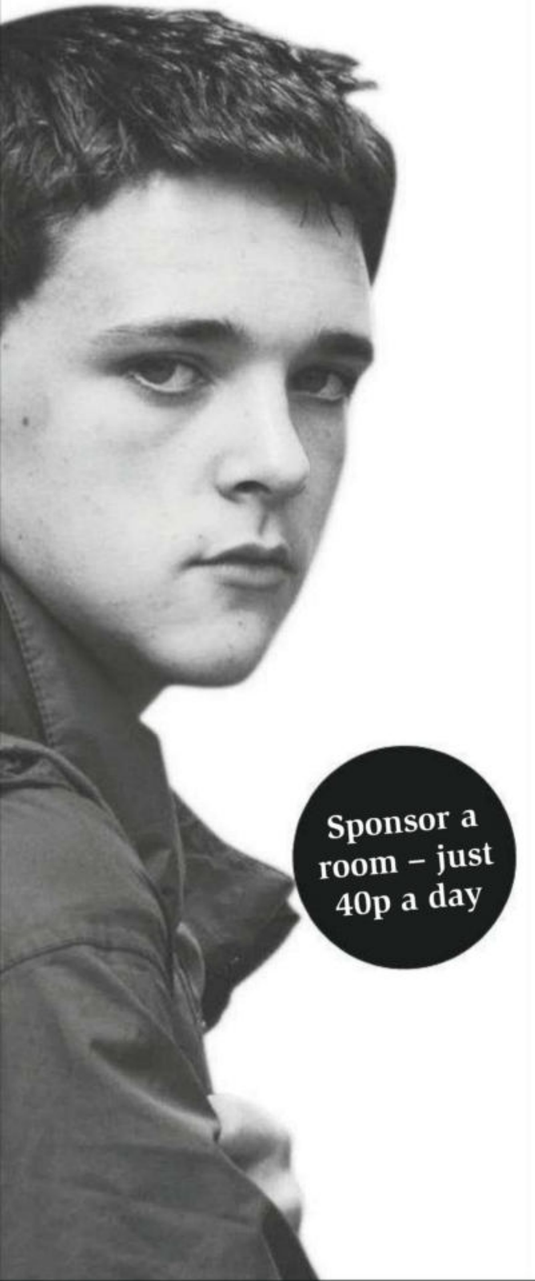
Even if new species don't lie at the bottom of mystery animal reports, the investigation of those reports sometimes remains worthwhile. A lake monster investigated on the Pacific island of New Britain turned out to be a crocodile, while the mermaid-like 'Ri' of New Guinea was shown to be a dugong. Had people not checked these stories out, they would have remained the stuff of legend.

The time has come to stop combing the Pacific Northwest of North America for Bigfoot, or looking for yetis in the Himalayas. But it doesn't follow that we should stop investigating all tales or accounts of mystery animals.

WHAT DO YOU THINK?

How can yetis, the Loch Ness monster and Bigfoot still elude us?
post@sciencefocus.com

You can't end homelessness. But you can end his.



Sponsor a room – just 40p a day

Like many of the homeless young people who come to Centrepoint, John is no stranger to being ignored. When he was just four his father walked out and the attention he got from his mum was far from hugs and kisses.

She showed him no affection and even his earliest memories were of her violence towards him. *"When I was five, Mum kicked me hard in the stomach. She was always shouting and would become violent."*

"I'd developed a nervous tick, but mum threatened to hurt me if I let anything show…It was too much to handle, too much commotion".

At 15 John started sleeping down by the canal and in a derelict high rise flat. Lonely and terrified, he turned to drink, self-harming and even became suicidal. When he finally ended up in hospital, his mother's response was to fly off on holiday. He'd never felt so rejected.

While John's story may sound shocking to you, many of the homeless young people who come to Centrepoint have been through similar experiences. They find themselves homeless after being victims of neglect, violence, sexual abuse and family breakdown.

By giving just 40p a day (£12 a month) you can get a vulnerable homeless person off the streets right now. You'll give them a room of their own and all the support they need to rebuild their life.

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Many people don't give homeless people like John a second glance, but today you can be the person who chooses not to ignore them.

Thanks to someone like you, John is now safe at Centrepoint.

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centre point give homeless young people a future

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centre point

The Analyst

Robert Matthews

A clever little trick that makes the invisible visible

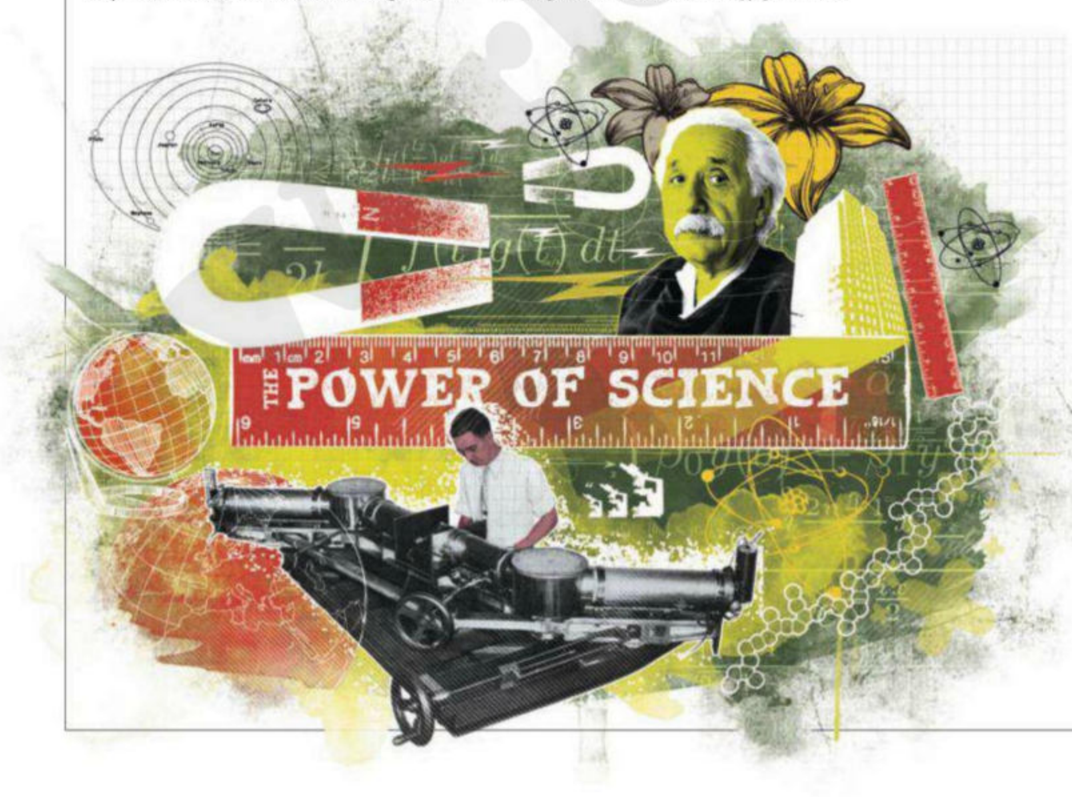
I'll never forget the first time I became aware of the power of science. It was during my second year at school, and a teacher was explaining how to work out the height of a tower without climbing it. All you had to do, he said, was measure the length of the shadow cast by an upright ruler, and compare it to the length of the shadow cast by the tower. A bit of geometry then gave the height of the tower in multiples of the length of the ruler.

Ever since, I've been a sucker for the simple scientific tricks that allow us to do incredibly difficult things. Need to know the circumference of the Earth, but can't face the walk? The ancient Greek Eratosthenes showed how, using some simple geometry and a couple of sticks to cast shadows at two places on the same day. Want to know what the atmosphere of Mars is like without going there? Simple: 19th-Century scientists showed how to split light using a spectroscope to reveal the glowing 'fingerprints' of different atoms anywhere from here to the edge of the Universe. Want to prove the existence of atoms without actually seeing them? Einstein showed it could be done by measuring the jitters of tiny particles inside pollen grains as they're hit by clouds of otherwise invisible atoms.

But sometimes even scientists are amazed at the ingenuity of others who do things that seem impossible – like creating a desk-top device that mimics the creation of energy in the Big Bang.

According to current theories of the cosmos, everything we see around us owes its origins to the quantum vacuum, an all-pervasive 'sea' of energy predicted to exist by the laws of the subatomic world. We're still immersed in it, in the form of a seething melee of energy and particles constantly flitting in and out of existence. The trouble is, the quantum vacuum is now so feeble that its existence has only been glimpsed in very delicate experiments.

> "Since school, I've been a sucker for the simple scientific tricks that allow us to do incredibly difficult things"



Theorists have tried to come up with ways of making it more obvious, and one involves having a mirror travel rapidly through a vacuum. Calculations show the mirror's reflective properties prevent some of the quantum energy disappearing back into the vacuum, so that it lingers long enough to be detectable. There's just one small snag, though: the mirror has to travel at around a billion km/h.

Now, amazingly, an international team of physicists led by Christopher Wilson at Chalmers University of Technology in Sweden has created just such a high-speed mirror, and used it to reveal the quantum vacuum.

They pulled off this impressive feat by exploiting the fact that it's not just shiny things that reflect: the same thing can be done using cleverly designed electromagnetic fields, which happily move at very high speeds. Having created such a 'weightless mirror', the team used a magnetic field to make it move back and forth at up to 25 per cent the speed of light. And to their delight, the quantum vacuum responded – by emitting microwave energy literally out of nowhere.

This isn't just an impressive demonstration of lateral thinking, though. As one scientist pointed out when describing the breakthrough in the journal *Nature* recently, it opens the way to laboratory studies of the ultimate source of everything in the cosmos. Now that's something that really would liven up physics practicals at schools.

DANHILLIARD.CO.UK

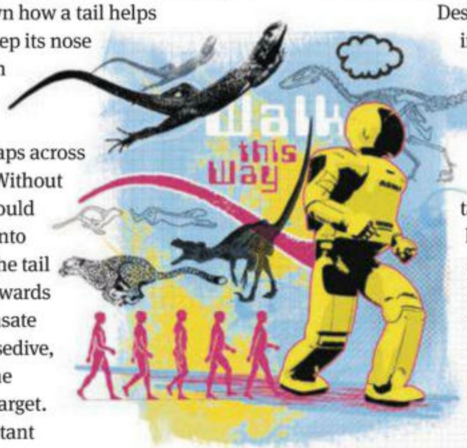
The Insider
Henry Gee

A tale of two tails and why we're still waiting for robot servants

Why does a lizard have a tail? It's obvious, right? Lizards use their tails to balance as they run. Well, yes and no. It's a little more involved than that. And it's an important thing to know because it could help us design better, more manoeuvrable robots and solve one of the most perplexing problems of biomechanics: how we manage to walk without falling over.

But first, to lizards and their tails. Professor Bob Full at the University of California, Berkeley, and his colleagues have shown how a tail helps a lizard keep its nose pointing in the right direction when it leaps across a chasm. Without a tail, it would nosedive into the gap. The tail swings upwards to compensate for the nosedive, keeping the lizard on target. The important thing is that the tail isn't just hanging passively in the air – the lizard moves it as an active stabilizer. The researchers proved this with a wheeled robot with an active, controllable tail. The results, published in *Nature* in January, confirm an idea put forward in 1969 about how dinosaurs such as Velociraptor ran and jumped.

Ongoing research, this time by scientists at the Royal Veterinary College in Hertfordshire, is also looking at tails – this time, on cheetahs. The tail, when thrown from side to side, allows cheetahs to remain stable when making right-angle turns at speed while in pursuit of prey. In other words, cheetah tails work like lizard tails, only from side to side rather than up and down. The researchers unveiled their findings at a recent meeting of the Society for Integrative and Comparative Biology at Charleston, South Carolina.



The secret here, then, is feedback. As an animal moves, it's constantly adjusting the angle of its tail relative to the rest of its body, monitoring the effects on movement and refining the adjustment further. In lizards, cheetahs and presumably dinosaurs, it all happens in split seconds.

Designers of realistic robots incorporate feedback like this into their creations, especially if they're going to be performing critical tasks a long way from human assistance. That means robots doing anything from rescuing victims in a disaster zone to exploring the surface of another planet.

Humans are inherently unstable and walking on two legs is really just controlled falling. But our posture is monitored at every instant by the balancing organs in our ears and stretch receptors in our muscles, which help the brain judge the right amount of feedback to provide. All this happens many times a second and yet we manage to walk every day without even thinking. But engineers still haven't cracked how to design humanoid robots that walk in a convincingly human-like way.

Having a tail seems to provide a distinct advantage when it comes to balance. So one day we will have robot servants but they'll probably have tails.

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MEET THE COLUMNISTS

The Insider
Henry Gee

A senior editor of the respected science journal *Nature*, Henry is the author of several books, including *The Science Of Middle Earth*.

The Eco-sceptic
Tom Heap

Tom is an expert on all things green. He presents *Panorama* on BBC One and *Costing The Earth* on Radio 4, which questions accepted truths on green issues.

The Analyst
Robert Matthews

After studying physics at Oxford University, Robert became a science writer. He is a visiting reader in science at Aston University.

The Medic
Michael Mosley

After training as a doctor, Michael joined the BBC to become a presenter, writer and producer. He's *The One Show*'s science man and presented *The Story of Science*.

The Medic
Michael Mosley

Is ice hockey bad for the brain?

When I was much younger I used to play rugby in a fearless fashion, putting my body and my brain on the line week in and week out. Then one wintry afternoon I got knocked unconscious by a kick to the head. The next thing I knew I was coming around to find myself lying on the side of the pitch. I had bad headaches for a few days after and decided it was time to quit before I did any further damage to my brain.

I was thinking about this when I read a recent report about an autopsy performed on a young Canadian ice hockey player called Derek Boogaard. Derek died in May last year aged 28. He had been consuming large quantities of painkillers, which probably contributed to his death, but it was what the neurologists found when they examined his brain that came as the real shock.

The outer surface of the frontal lobe of Derek's brain was speckled with brown spots, signs of a condition known as CTE, chronic traumatic encephalopathy. CTE is thought to be caused by repeated, severe blows to the head. It's a progressive, degenerative disease that can lead to early dementia.

Professional ice hockey is often violent. As his team's 'enforcer', Derek was expected to fight with the opposition. One of the ironies of his condition is that damage to the frontal lobe can lead to greater aggression, meaning he'd be more likely to get into fights, leading to further brain damage. Since Derek, a couple of other enforcers have also died.

Nobody knows how much, if at all, Derek's brain damage was a direct result of the blows taken during his playing career. And even if they did know, would violence in the game be outlawed? In boxing the link between blows to the head and increased risk of brain damage in later in life is clear. Yet the bouts continue. It's not my idea of sport, but then I am a wimp.

WHAT DO YOU THINK?

How can contact sports be made safe?

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Home from home

Your feature 'Virtual Worlds' (February, p62) begs the question, what will happen as exoplanet discovery continues? We know they are there – some are in the habitable zone and some are a little like Earth. Well, sort of. As our technical ability to glean more details from our observations grows, we will no doubt find a more exact match, maybe signs of life or even signs of civilisation – as John Gribbin's new book *The Reason Why* suggests, you never know.

Stephen Hawking, among others, points out that the future of humanity on this planet is doomed, albeit in the long term. Changes to our Sun will inevitably destroy us, and if we want to secure humanity's long-term future then we must explore the Universe. Indeed, we must find new homes. How future science might achieve this is, of course, unknown, though technical progress continues to amaze us. Maybe the proven discovery of real mirror-Earths will get doubters taking a different view. Kepler-22b (page 22 of your February issue) may not be quite the one but it surely cannot be too far off.

The alternative to pursuing this line would surely be rather like early man deciding that the African plains were more than enough.

Patrick Forsyth, Maldon, Essex

We must look to exoplanets for our future, says Patrick Forsyth

How to save the planet

You invite comments in your December issue, page 23 ('Can we solve climate change with geoengineering?') No, I absolutely do not want us messing around with the planet to try to 'save' it! I want it to be recognised that human numbers are the most important factor, in the mathematical sense, in climate change, and therefore every country should adopt non-coercive policies to bring down the global population to a sustainable level, say 1 to 2 billion.

Venetia Caine, Somerset

Re: Michael E Mann's article on geothermal engineering, building carbon catchers will work but surely at a price. Why, if the removal of trees over the last 50-100 years is the main cause, is the mass planting of trees over the next 30-50 years not put forward as a solution?

I am proposing that countries calculate the surface area of trees removed and, according to each country's CO_2 output, agree to plant a certain amount of trees to replace those lost.

Berita Blaauw

With the population of Earth currently over 7 billion, reducing it to 2 billion is a big ask – that number had been surpassed by the 1930s. Regarding trees, wouldn't mass planting be costly too? ***– Ed***

The invisible man

I successfully demonstrated a cloaking effect in 1961, as a young technician working in the chemistry department at Nottingham University. I made up a mixture of chloroform and carbon tetrachloride to get it to the same refractive index as pyrex glass. I put it in a 500ml bottle, dropped in a piece of pyrex tube and labelled it, 'Shake me'. Someone would

WHAT DO YOU THINK?

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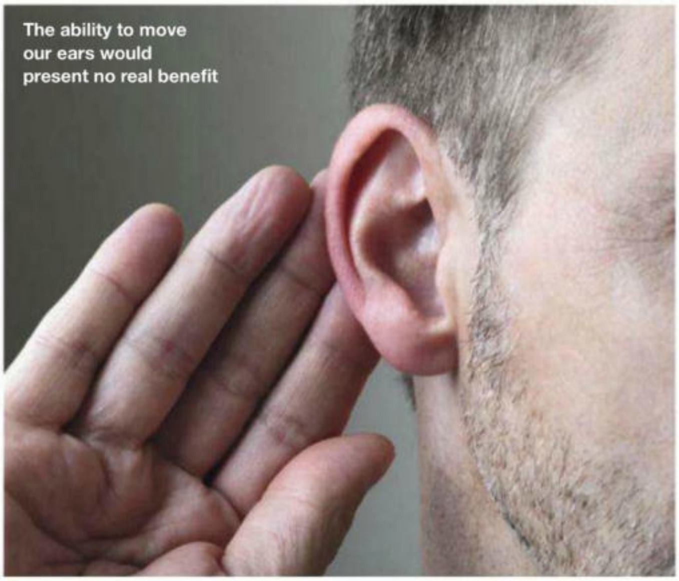

The ability to move our ears would present no real benefit

pick it up, shake it and hear the tube rattling inside... but it was completely invisible!
David Oldfield

Ear me out

I would like to expand on the answer given by Susan Blackmore to the question, 'Why can't we move our ears?' in the January issue. The convoluted shape of the concha (inside form of the outer ear) has evolved to attenuate certain sound frequencies. The degree of attenuation and the affected frequencies vary according to the angle at which the sound strikes the concha. Therefore the sound in one ear will always differ from that received in the other ear.

To determine the nature of the sound, the brain combines the sounds from both ears, but to determine the direction it compares them. Because this works for short-duration sounds such as a twig snapping, where turning the head or ears would be too slow, it is likely to have evolved along with our fight-or-flight features for protection and survival. Movement of the ears would simply increase the complexity of the process without any great benefit.
John Corfield, Devon

Burning up

The answer given in January's edition to the question 'What causes spontaneous human combustion?' is, I feel, not a satisfactory one. The response talks of an external heat source from a cigarette or spark being the ignition source. The fuel is the clothing supposedly ignited by the spark, which then produces additional fuel from body fat, heated by the burning clothing.

This process, started from outside the body and burning inwards, does not constitute 'spontaneous combustion'. That would be a substance or material igniting without an external heat source, such as bacterial activity within a straw stack. One view that has been mooted is that it could be caused by bacterial activity inside the body but presumably this would have to be within the lungs, this being the only part of the body containing sufficient oxygen in a form which could be ignited.
Gary T Spooner

Luis Villazon replies:
If we adopt your narrower definition of SHC, I would argue there is no evidence it exists at all. None of the documented cases require internal ignition to explain them and there is no known plausible mechanism by which it could occur – bacterial decay doesn't generate anywhere near enough heat to dry out the water in a person.

If your hypothesis were true, we might expect to observe SHC in mass graves, where bodies are stacked together and the heat could build up.

Let's hear it for the nose

Your January issue had a good, informative article on dust ('The secrets of dust', p69). But it is beyond belief that, having stressed that it has an impact on human health, there is no mention of how the human nasal tract has developed the most sophisticated air filtration system, which only nature could come up with. I earn my living by knowing how it works, why and how it sometimes goes wrong and how to restore it to its full working capacity. Few people realise that the nose has a far more important job to do than merely recognise smells: its main purpose is, in fact, to protect the lungs from receiving unclean air.
Mike James, Isle of Man

Oops!
The answer given in January's quiz to question 5 was incorrect. It should have been C (Britainium), not B (Californium).

On page 11 of January's issue, the picture showed a dye tracer experiment taking place on an ice sheet in Greenland. The project is similar to the one at Plaine Morte Glacier in Switzerland, which was described in the text.

Competition winner
Congratulations to Colin Bailey (Portsmouth) who was the winner of the competition in December's issue. He wins an Olympus E-PM1 camera and lenses.

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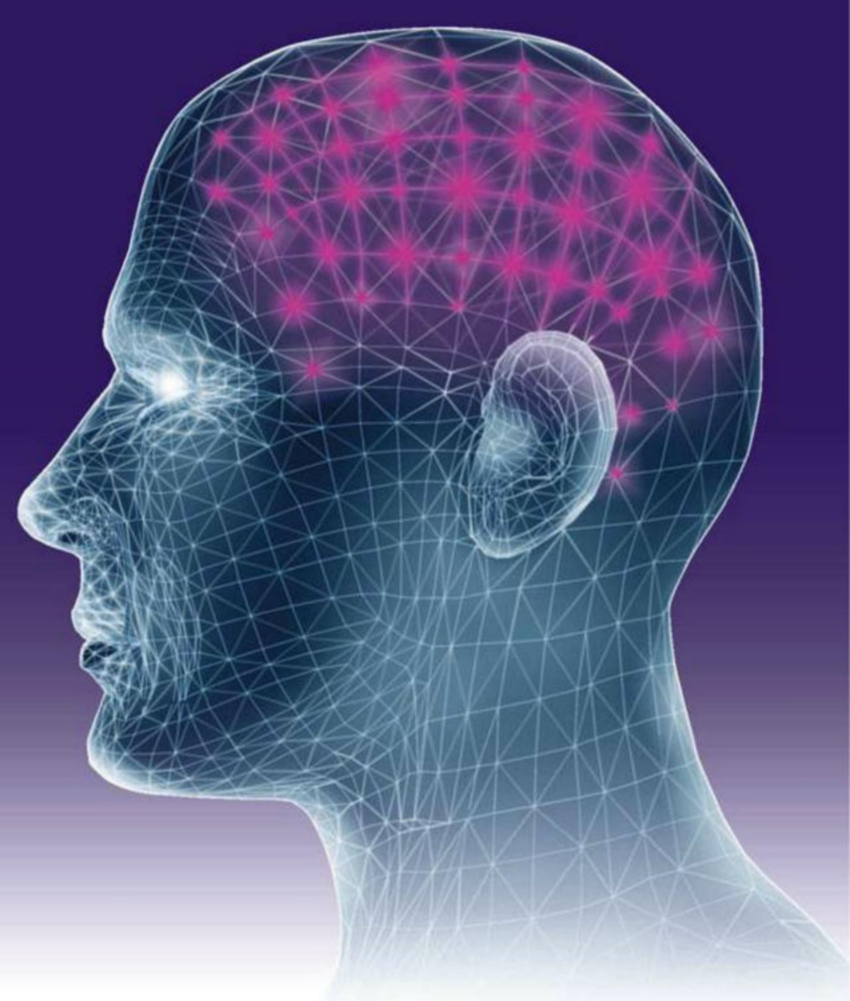

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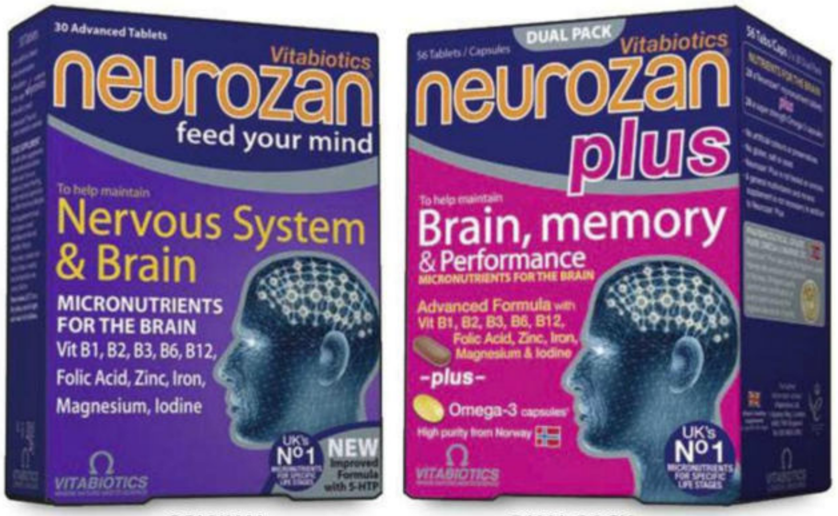
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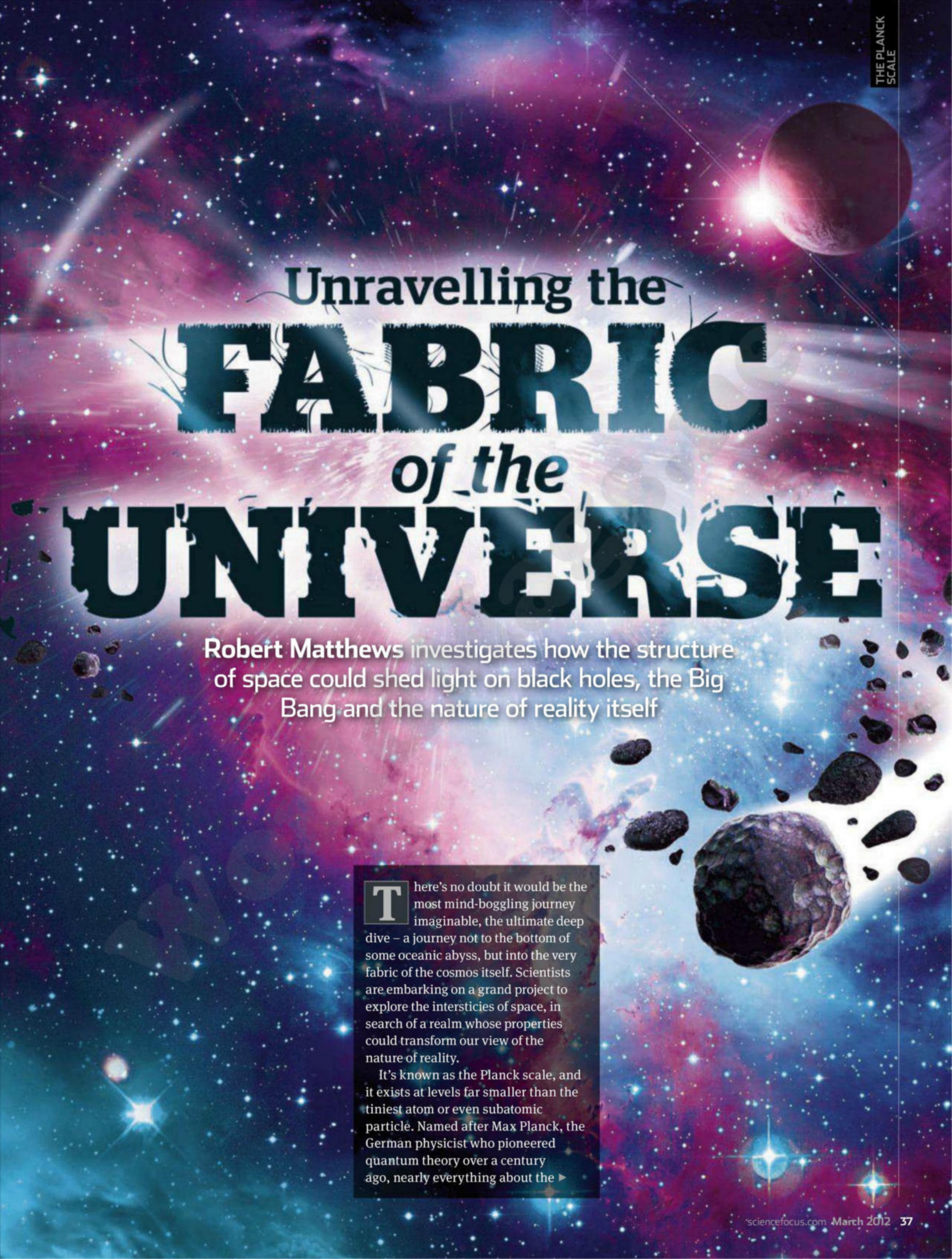


Unravelling the FABRIC of the UNIVERSE

Robert Matthews investigates how the structure of space could shed light on black holes, the Big Bang and the nature of reality itself

There's no doubt it would be the most mind-boggling journey imaginable, the ultimate deep dive – a journey not to the bottom of some oceanic abyss, but into the very fabric of the cosmos itself. Scientists are embarking on a grand project to explore the interstices of space, in search of a realm whose properties could transform our view of the nature of reality.

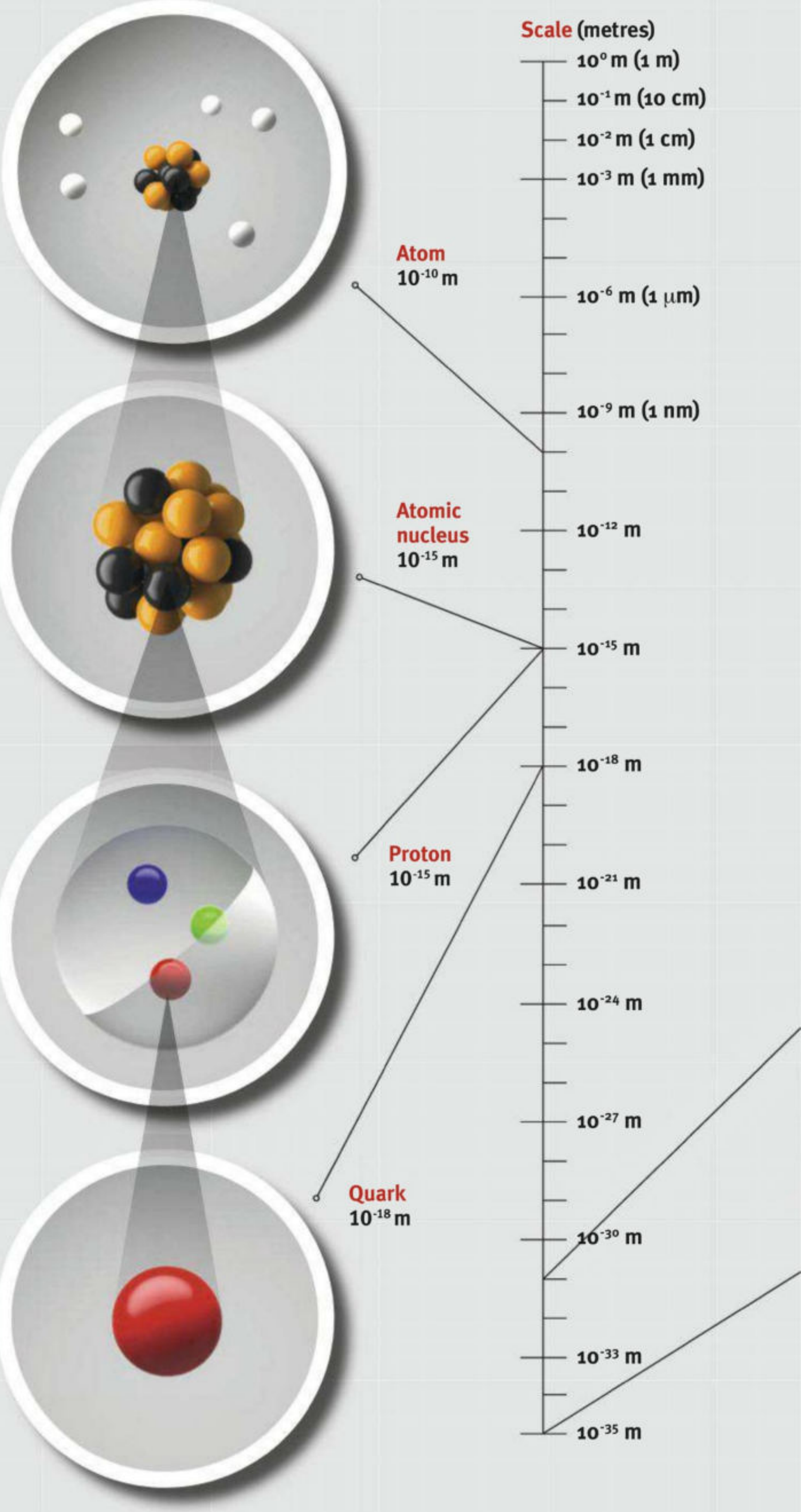
It's known as the Planck scale, and it exists at levels far smaller than the tiniest atom or even subatomic particle. Named after Max Planck, the German physicist who pioneered quantum theory over a century ago, nearly everything about the ►

WHAT IS THE PLANCK LENGTH?

Comprehension-defyingly small distances explained

The Planck length is the scale at which our commonsense notions of what space is like break down. But why is it so small? The answer comes from attempts to combine the two most successful theories in physics: quantum theory, which rules the subatomic world, and Einstein's theory of General Relativity, which describes gravity and the behaviour of space and time.

Each involves fundamental constants that dictate the strength of effects predicted by the two theories. When combined, these fundamental constants also predict the scale at which the two theories are both needed to describe the basic structure of space and time – and the result is known as the Planck scale of just 10^{-35} metres. If you were to write it as a number, it would have 34 zeros after the decimal point.



NASA X2, ILLUSTRATION BY JUSTIN METZ

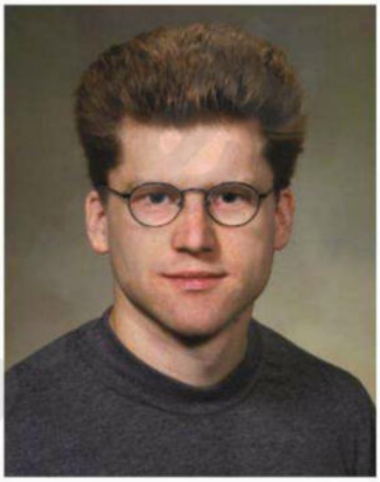
Planck scale beggars belief. Today's best microscopes can achieve magnifications of around 100 million times, which is just about enough to reveal individual atoms. To do the same for events on the Planck scale, you'd need a microscope 10 million billion billion times more powerful still. Put another way, you'd need magnifications so great that individual atoms would appear bigger than entire galaxies.

Yet despite the challenges involved, scientists believe they're closing in on the Planck scale. They've already come up with some insights by exploiting cosmic events as awe-inspiring as the challenge itself. And some suspect the first glimpses of the stitches in the fabric of the Universe may emerge from experiments that are underway right now.

The first results are eagerly awaited by theorists wrestling with some of the deepest mysteries in science – including the birth of the Universe from an incredibly compact state, nearly 14 billion years ago. "The structure of space-time is the new and perhaps last frontier on our way to a complete understanding of nature," says theorist Professor Martin Bojowald of Penn State University. "The Planck scale is crucial for our understanding of the Big Bang and what's at the centre of black holes."

According to Prof Bojowald, scientists may now be standing at the edge of a whole new view of reality as profound as that which followed the

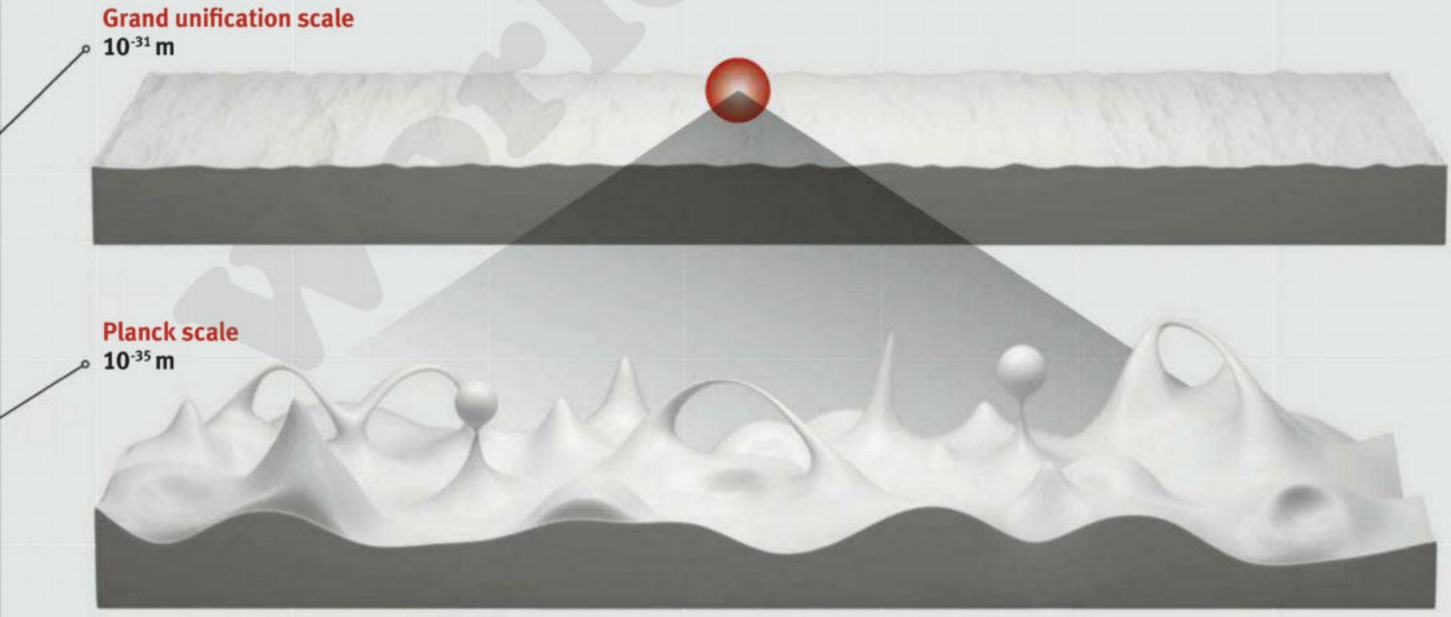
On the Planck scale, atoms would appear bigger than entire galaxies



Prof Martin Bojowald of Penn State University believes we're at the beginning of our understanding of the Planck scale

DOWN AT THE BOTTOM

So what would space look like down at this unimaginably tiny scale? Nobody knows for sure, but one possibility is that it would be like viewing the ocean from different heights: apparently smooth when seen at large scales, but increasingly rough and foamy the closer you get to the Planck length.



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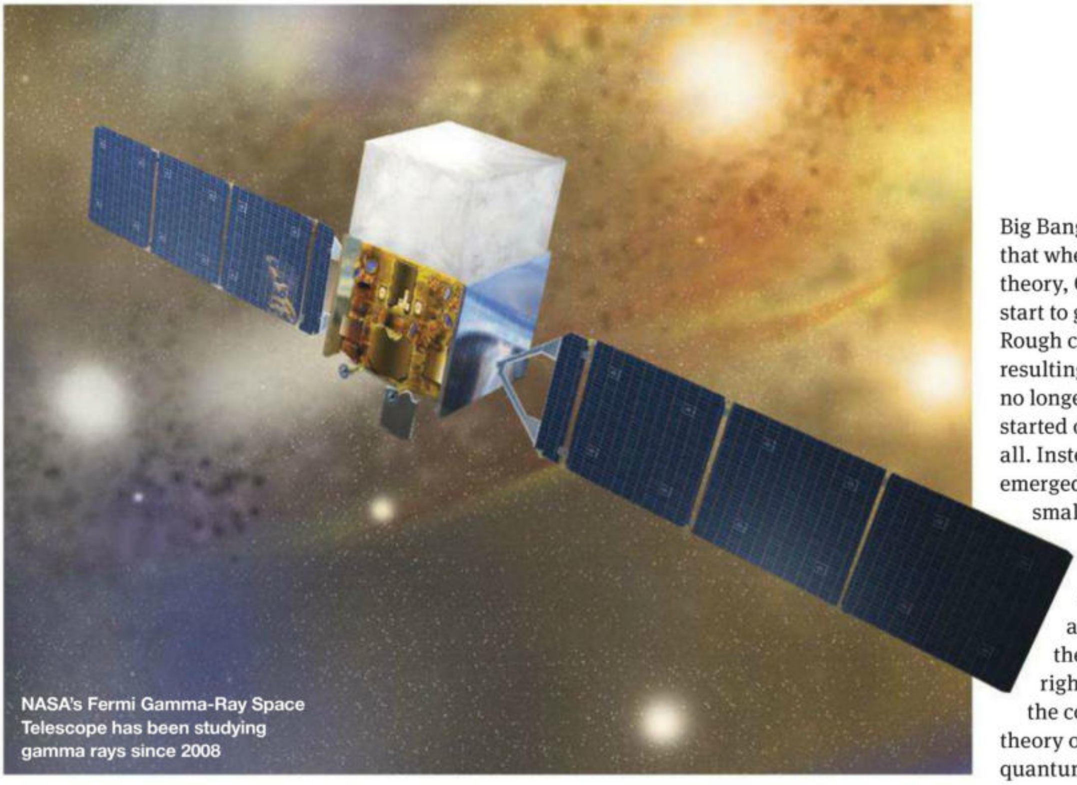


NASA's Fermi Gamma-Ray Space Telescope has been studying gamma rays since 2008

▶ proof of the existence of atoms just a century ago. "We now know what the atomic nature of matter implies, but for space-time we're still working at a level comparable with 19th century physics," he says. "If Planck scale effects can be detected, we can test and improve our theories about it."

Changing ideas

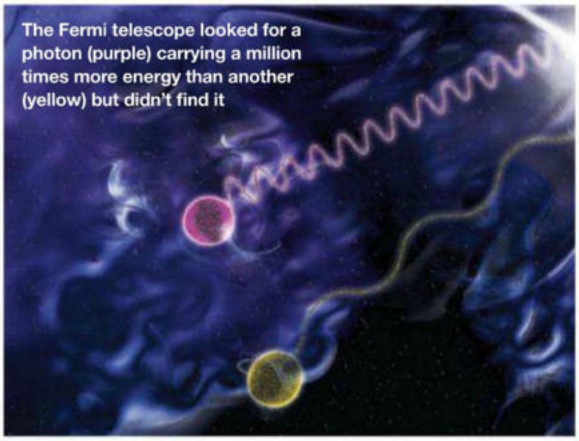
While attempts to reach the Planck scale are at the cutting edge of 21st century science, suspicions about the true nature of space and time date back millennia. In the 5th century BC, the Greek philosopher Zeno of Elea argued that the 'commonsense' notion of space and time being infinitely divisible leads to paradoxes. He pointed out that if space is infinitely divisible, the very idea of moving from one point to another becomes problematic. Yet in everyday experience, there doesn't seem to be a problem – which suggests there may be something wrong with the idea that space *is* infinitely divisible.

Glimmerings of quite what the problem is didn't emerge until the mid-1950s, when theorists began attempting to unify the two great theories of modern physics: quantum theory, which governs the subatomic world, and Einstein's theory of gravity, known as General Relativity.

Theorists had recognised that only such a unified theory could explain the mystery of the Big Bang, when the whole of the Universe had burst forth from some unimaginably compressed state. By itself, Einstein's theory of gravity was not up to the job: its equations simply went haywire when trying to describe the instant of the Big Bang. But theorists suspected that when combined with quantum theory, General Relativity might start to give sensible answers again. Rough calculations suggested that the resulting theory of 'quantum gravity' no longer implied that the Universe started out with literally no size at all. Instead, it suggested the cosmos emerged from a state of incredibly small but finite size roughly equal to the Planck scale.

But the implications of quantum gravity don't stop at the Big Bang. They affect the nature of space and time right here and now – through the combined effect of Einstein's theory of gravity, plus the famous quantum uncertainty principle. ▶

> *"For space-time we're still working at a level comparable to 19th century physics"*



The Fermi telescope looked for a photon (purple) carrying a million times more energy than another (yellow) but didn't find it

KEY EVENTS

A brief history of our understanding of space-time

460BC

Zeno of Elea shows how the idea that distances can be infinitely divided leads to paradoxes, hinting that 'commonsense' views of space may be misleading.

1899

German physicist Max Planck puts forward a fundamental and incredibly small unit of length – the Planck scale, now recognised as the scale at which space loses its 'commonsense' properties.

1915

Albert Einstein publishes his theory of gravity, known as the General Theory of Relativity, which reveals a fundamental connection between space, time and the force of gravity.

1955

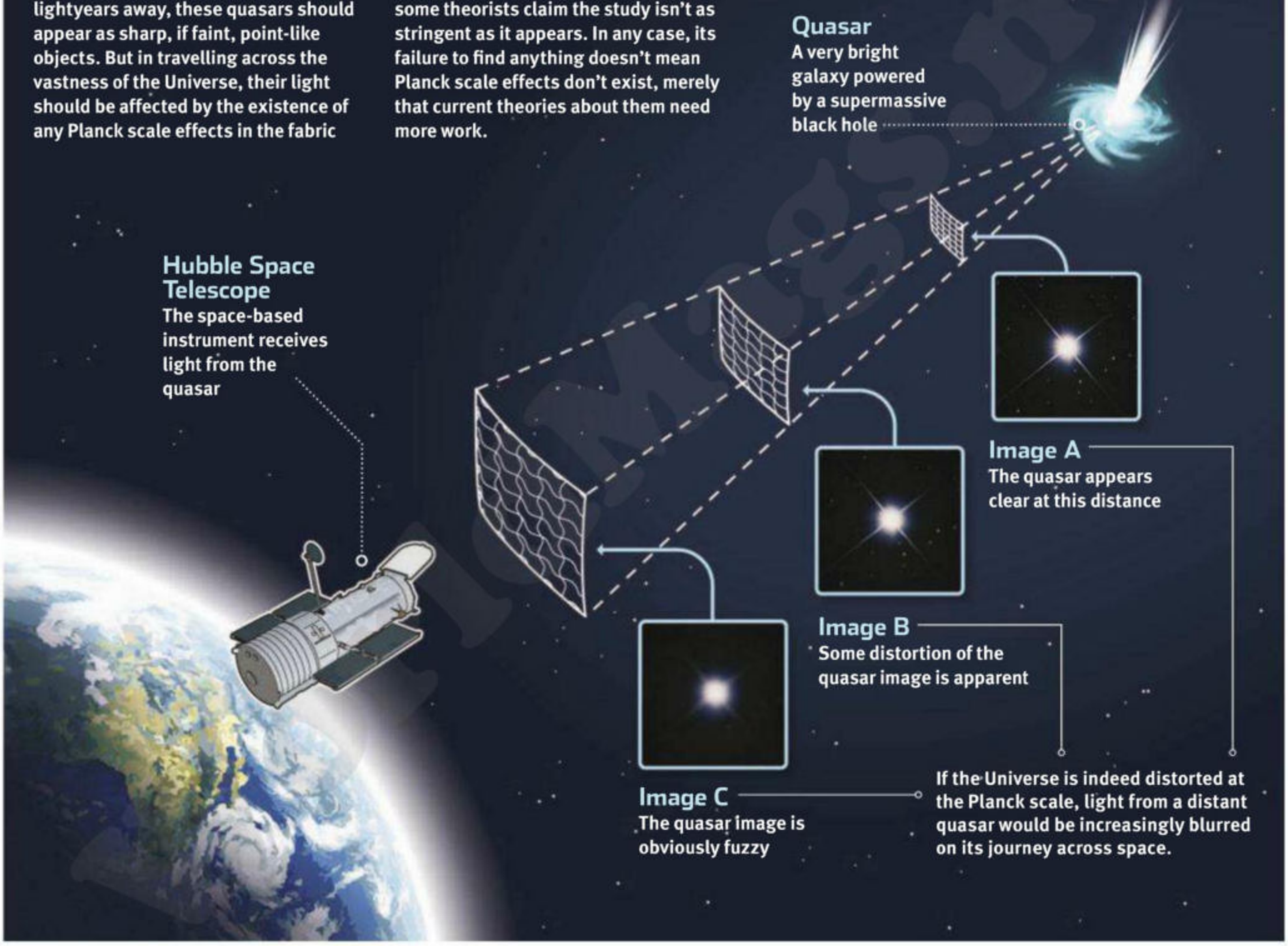
NASA X2, ILLUSTRATION BY ACUTE GRAPHICS, CORBIS X2, SCIENCE PHOTO LIBRARY

STUDYING THE FABRIC

How the Hubble Space Telescope acts like a giant 'microscope'

Last year, a team of scientists led by Fabrizio Tamburini at the University of Padua, Italy attempted to detect Planck scale effects using the power of the orbiting Hubble Space Telescope (HST). To do it, the team analysed images of quasars, the incredibly bright central regions of galaxies on the edge of the visible Universe. As they lie billions of lightyears away, these quasars should appear as sharp, if faint, point-like objects. But in travelling across the vastness of the Universe, their light should be affected by the existence of any Planck scale effects in the fabric of the cosmos. And because the effect is cumulative, by the time the light reaches the Earth, the images should be increasingly blurry

After analysing the images of over 150 quasars taken with the HST, the team came up empty – there was no sign of any Planck scale effects. The implications are still being argued over: some theorists claim the study isn't as stringent as it appears. In any case, its failure to find anything doesn't mean Planck scale effects don't exist, merely that current theories about them need more work.



Quasar
A very bright galaxy powered by a supermassive black hole

Hubble Space Telescope
The space-based instrument receives light from the quasar

Image A
The quasar appears clear at this distance

Image B
Some distortion of the quasar image is apparent

Image C
The quasar image is obviously fuzzy

If the Universe is indeed distorted at the Planck scale, light from a distant quasar would be increasingly blurred on its journey across space.

1985
American theorist John Wheeler posits the concept of space-time foam: the roiling turbulence of space and time expected at the Planck scale according to some theories.

2008
Theorists trying to combine Einstein's theory of gravity with quantum theory produce new views of the nature of space and time at the Planck scale, such as the Calabi-Yau manifold.

2011
Astronomers using the Fermi orbiting observatory detect gamma rays from an explosion halfway across the Universe. Their behaviour shows no evidence of Planck scale effects.

Attempts to detect Planck scale effects by studying radiation from exploding stars and distant galaxies draw a blank, raising questions about some theories of Planck scale phenomena.

"Something else very exotic, transcending our current understanding, could be going on at the Planck scale"

▸ According to this, certain properties of apparently empty space are intimately connected. In particular, the more precisely a region of space is defined, the more uncertain its energy content becomes. Einstein's theory of gravity predicts that this will lead to space-time becoming ever more distorted. The level of distortion increases the smaller the volume of space becomes, reaching its most extreme at the Planck scale.

"If something is localised to a region smaller than this scale, the gravitational warping is likely to be so great that the entire region is engulfed in a mini black hole," says quantum gravity expert Professor Ted Jacobson of the University of Maryland. "So at the Planck length scale, space-time is warped in the extreme."

A question of scale

The details of what happens to the fabric of the cosmos down at this scale aren't clear, and various scenarios have been put forward (see 'Beyond Einstein', right). But most suggest that right now, all around us, space and time are undergoing unimaginable contortions on the Planck scale. At least, they are if quantum theory and relativity still hold at that level. But that isn't guaranteed by any means, Prof Jacobson cautions.

"If they don't hold, something else very exotic – transcending our current understanding – would be going on," he says. "Either way, things are likely to be 'interesting' at the Planck scale."

There's only one way to discover just how interesting it is: devise some methods for probing the nature of space and time down there. And astonishingly, scientists have already come up with ways of doing just that – with tantalising results.

Ironically, so far most progress has been made via studies of events that take place on truly titanic scales. The reasoning is simple enough: even the tiniest effects can be made detectable if they're given the chance to accumulate. And in the case of Planck scale phenomena, that means looking for their telltale signs in events at huge distances from the Earth.

It's a strategy first tried out by astronomers using NASA's Fermi space telescope. Launched in 2008, Fermi is able to detect gamma rays – the most penetrating form of radiation unleashed by the most violent events in the Universe. In May 2009, Fermi detected a two-second blast of gamma rays coming from a galaxy over 7 billion lightyears away. Among the radiation making up this blast, astronomers detected two rays whose wavelength – and thus energy – differed by a factor of a million. This made them perfect for testing one theory about the Planck scale: that the contortions may be so violent that they violate Einstein's famous rule that all radiation travels through empty space at the speed of light.

Some theorists have claimed that the result would be significant differences in speed, according to the energy of the radiation. Yet despite the huge contrasts in their energy, the two gamma rays struck Fermi's detector within 0.9 seconds of each other – after a journey lasting over 7 billion years. According to Fermi scientist Peter Michelson of Stanford University, California, that's bad news for theories about the Planck scale that try to undermine Einstein's venerable theory. "These two photons travelled at the same speed, to one part in 100 million billion," he says. "Einstein still rules."

Since then, scientists have conducted several more searches for Planck scale effects. Last summer, Dr Philippe Laurent of the Saclay research centre in France and his colleagues published a study of

BEYOND EINSTEIN

The quest for a Theory of Everything

One of the biggest questions surrounding the Planck scale is what happens to space and time down there. One idea is that it will take the form of space-time foam, a little like the surface of a wind-swept sea. But most theorists believe the truth will only emerge if they find the Holy Grail of physics: the Theory of Everything (ToE).

The quest began almost a century ago, when Einstein tried to develop a single set of equations to describe the forces of both gravity and electromagnetism. He never found his 'unified field theory' – which, in any case, failed to incorporate forces of nature discovered later.

Now, theorists think they know how to create a ToE: combine Einstein's theory of gravity, known as General Relativity (GR), with quantum theory, the rules of the subatomic world. The challenge lies in marrying their different approaches to describing fundamental forces.

Attempts to combine these approaches soon ran into mathematical problems. But in the mid-1980s theorists made a breakthrough. Many of the problems disappeared if everything, even space and time, is made up of 'superstrings'.

These multidimensional objects are thought to have two key properties. They're incredibly small: roughly the same size as the Planck scale. And they have at least 10 dimensions, of which six are curled up into incredibly complex shapes known as Calabi-Yau manifolds.

Superstrings seem to solve the problems of unifying quantum theory with GR. Together, these properties point to a new vision of the 'fabric' of the cosmos. At the Planck scale, space wouldn't be smooth and regular, but nor would it be chaotic. Instead it'd be like a vast plain dotted with the Calabi-Yau manifolds.

There are other possibilities, though. Another way of unifying gravity and quantum theory is called Loop Quantum Gravity theory. This theory points to the fabric of the cosmos being made from tiny loops.

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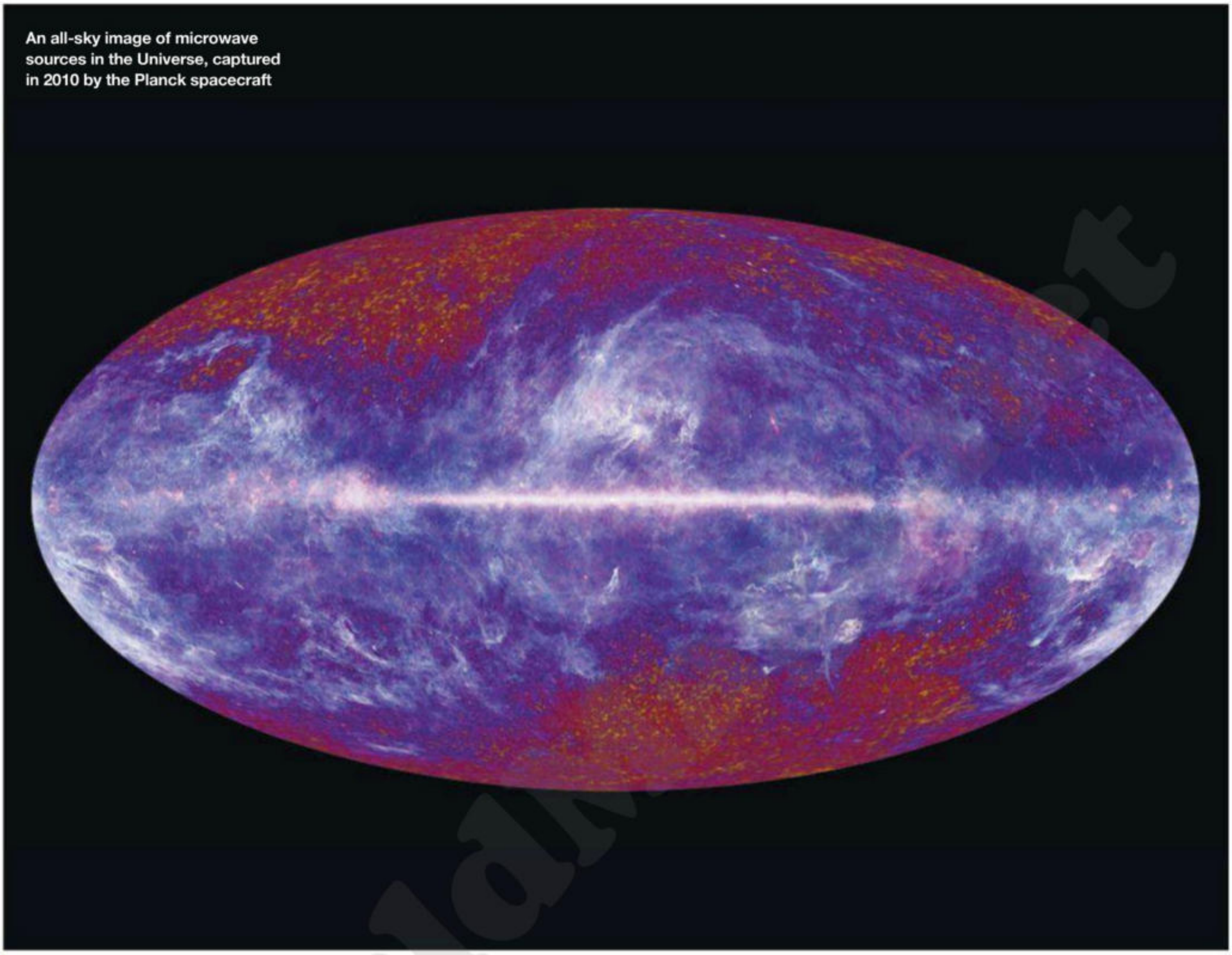

An all-sky image of microwave sources in the Universe, captured in 2010 by the Planck spacecraft

gamma radiation detected in 2004 by the European Space Agency's Integral satellite. According to some theorists, Planck scale distortions of space and time should put a detectable twist, or polarisation, into the gamma rays as they travel through empty space. Yet Dr Laurent's team were unable to find any evidence of polarisation in the gamma rays – ruling out another swathe of theories.

> *We may reveal what space and time were like when the fabric of the cosmos was created*

Late last year, a team led by Fabrizio Tamburini at the University of Padua, Italy published a study looking for Planck scale 'fuzziness' in images of distant galaxies taken by the Hubble Space Telescope (see 'Studying the fabric', p41). The implications of the results are still hotly debated, but it seems that they too have succeeded only in ruling out some theories of the Planck scale.

So could the search for the stitches of space-time prove to be a wild goose chase? "What's been compared with observation so far are the most optimistic scenarios," says Prof Bojowald. "It's not surprising that many of them can be ruled out."

He believes major clues may emerge soon from studies of the heat left over from the Big Bang. Spread throughout space, this remnant of the birth of the Universe is being scrutinised by an ESA satellite known, appropriately, as Planck. Over the next year, astronomers will be releasing results that may cast light on events that took place when the whole Universe was barely bigger than the Planck scale.

According to Prof Bojowald, there's a chance these results may reveal what space and time were like when the fabric of the cosmos was created. "Many Planck scale theories differ in their predictions, and we may be able to distinguish between them using this new information."

Nobody knows yet what the outcome will be. Einstein's century-old concepts may prevail – or they may collapse to reveal an astonishing new vision of the nature of space and time. But one thing is certain, says Prof Bojowald: "We should keep our eyes open for surprises." ■

Robert Matthews is Visiting Reader in Science at Aston University

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The Science Of CHEMICAL ATTRACTION

Perfumes and other airborne aromas can tell a potential partner a lot about you. **Sarah Castor-Perry** reveals the science of sexy scents

Perfumes are made from sexy secretions

The 'top notes' of perfumes – the small, volatile molecules we smell first – are highly scented and often come from the secretions of flowers. 'Mid notes', which can include frankincense (above) will give perfumes an overall 'roundness', whereas base notes are heavy molecules designed to linger long after the scent is applied. The mid notes also disguise the initially unpleasant initial smell of base notes, whose chemical compositions are often similar to sex hormones secreted by mammals.

Flowers smell like insect pheromones

Red roses are not the only option for Valentine's Day. Most perfumes contain floral elements, which often aim to mimic insect pheromones and attract pollinators. These secretions are extracted directly from the flower or designed to imitate their scent. From jasmine and rose to gardenia and orange blossom, floral elements form an important part of a perfume's bouquet.

Fragrances come from peculiar places

Musk (a base note with a woody, animal aroma) was originally extracted from the **anal scent glands of the African civet cat** or musk deer. Ambergris is even weirder: it's a waxy substance regurgitated by sperm whales in response to stomach irritation. Freshly thrown-up ambergris isn't easy on the nose but, as it floats and ages, it develops an aromatic, earthy scent. Ambergris is so rare that in 1908, a lump weighing 500kg sold for the equivalent of £500,000. Musk and ambergris have been replaced by synthetic alternatives because the animals that produce them are now protected.

Personality influences which perfumes we pick

In the 1980s, the 'fragrance psychologist' Joachim Mensing found that **extroverts prefer fresh scents, such as citrus notes** like bergamot (above). Introverts prefer the perfumes of eastern Asia, including sandalwood and jasmine, and those with 'emotional instability' like powdery florals, like roses and violets. Mensing went on to work with Estée Lauder and Davidoff.

DAVID HOSKING/FLPA, THINKSTOCK, SCIENCE PHOTO LIBRARY X2, ILLUSTRATION BY MAGICTORCH

Chemists reverse-engineer natural aromas

If you love a smell, you can bottle it. Thanks to so-called headspace technology, chemists are able to place an airtight glass sphere or flask around a flower or object, suck out the air, and trap the volatile scent compounds in a filter. These are analysed using gas chromatography and mass spectrometry to determine a scent's recipe, which can then be synthesised in a lab. One example of the headspace technology created by perfume manufacturers is the 'Living Flower' system, invented by Braja Mookherjee of International Flavors and Fragrances in 1985.

We can smell genetic compatibility

In 1995, Claus Wedekind had women sniff t-shirts worn by men for two days, then rate how attractive they thought the owners were. Genetics revealed that women prefer the smell of a man with major histocompatibility complex (MHC) genes that differ from their own. More variety in MHC improves the immune system's chances of fighting infections, so women might pick mates based on potentially producing healthier kids.

We can also smell symmetry

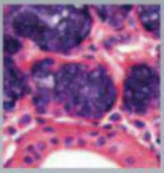
In another sweaty t-shirt study, Randy Thornhill showed that women prefer the smell of men with symmetrical faces, and this preference is highest when a woman is ovulating. Symmetry is thought to reflect genetic quality and a lack of undesirable mutations. Symmetrical men have higher-quality sperm, larger bodies, more attractive faces and are socially dominant. Women are also more likely to have an affair with symmetrical men – their evolutionary urge to pass good genes to their offspring overtaking the social desire not to cheat on their partners.

Noses detect vibrations

How do the molecules in scents produce the 'smell' we perceive? Some scientists claim that olfactory receptors in our noses respond to the shape of scent molecules. But biophysicist Luca Turin believes we distinguish between molecules based on how they vibrate at different frequencies. Turin has supported this theory by showing that two molecules with different shapes can both have a sweet, tobacco-like smell. This allowed him to create synthetic, useable alternatives to molecules that smell nice, but are too toxic for perfumes.

Humans produce pheromones

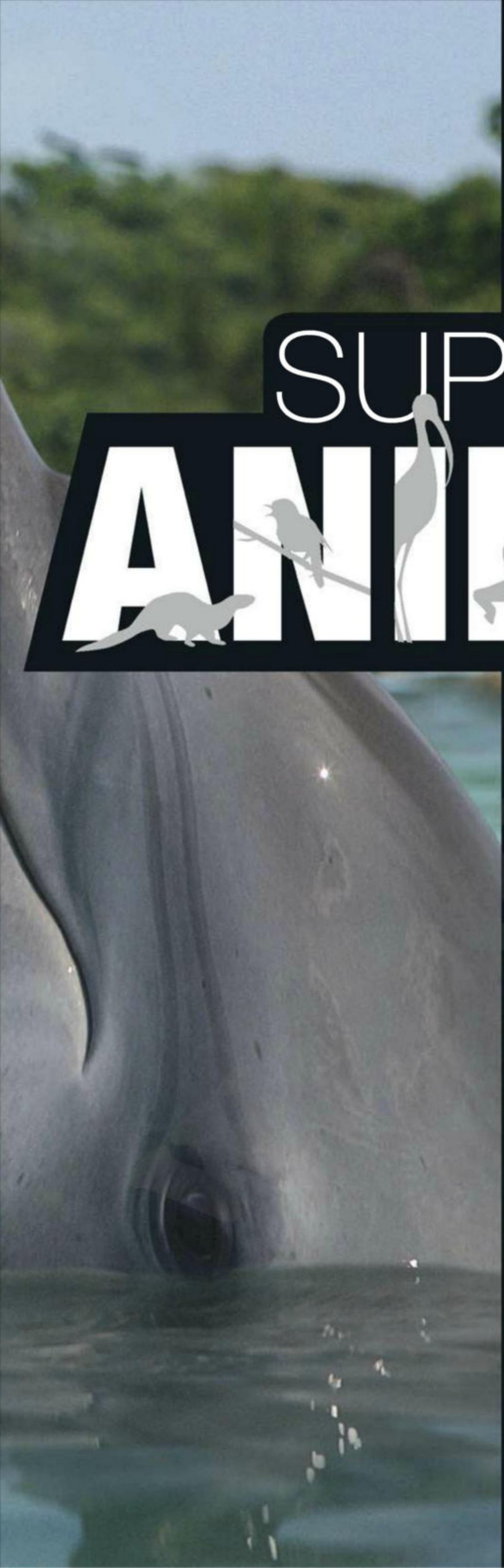
Some animals secrete pheromones, chemicals that affect another individual's mood or behaviour. Detecting pheromones requires a 'vomeronasal organ'. Despite not having a working organ, our bodies *do* release chemicals that could be considered 'pheromones'. In 2007, evolutionary psychologist Geoffrey Miller showed that **lap dancers get higher tips when they're most fertile**, suggesting that women give off sexy chemicals, while Saul Miller found that male testosterone levels increased when exposed to the scent of an ovulating woman.



Hairy armpits show off scents

Underarm skin contains apocrine sweat glands (above) that release – mainly odour-free – sweat and pheromones. Hair provides a great breeding ground for bacteria, which will work on secretions in our underarm body odour and enhance their natural aromas. In the 1950s, dermatologist Walter Shelley found shaved armpits were less likely to be described as "odourous".

BBC



SUPER ANIMALS

Are humans really the smartest species? For a new BBC series, biologist and TV presenter **Liz Bonnin** meets the clever creatures that could rival us

The test seems simple enough: recall the numbers one to nine, in the right order, after they appear randomly on a computer screen. Each number only flashes up for 60 milliseconds – faster than the blink of an eye, and too fast for me to remember. The challenge is taking place at Kyoto University in Japan, where I'm up against 11-year-old Ayumu. I score zero out of 10, he gets top marks. Ayumu is a chimpanzee.

Being beaten in a memory test is just one of many examples of how humans aren't always the smartest species. Intelligence isn't easy to define, even in humans – it has facets beyond aspects like memory and IQ, with some people being better at different things. Intelligence is a relative term that can't be measured, and includes the ability to plan, learn, solve problems, think abstractly, and comprehend complex ideas.

So it's not surprising that assessing intelligence in other animals should be even more of a challenge, especially since science traditionally uses tests designed for humans to evaluate others. And if any group should fare better than most in such tests, it's the apes.

Tetsuro Matsuzawa, professor of language and intelligence at Kyoto University, believes that there may be an evolutionary basis to Ayumu's amazing memory skills: chimpanzees commit their environment to memory much faster than humans because, to survive, they must assess a situation extremely quickly. When our ancestors acquired language skills, this ability had to make way for the more cognitively demanding task of representing memory linguistically – how we retell our experiences to others.

Ayumu's performance not only forces us to reconsider our definitions of intelligence, it also suggests that many animals are already as intelligent as they need to be for their environment. Across the planet, animals are proving capable of the intellectual achievements once believed to be unique to humans, showing us that they're far more intelligent than we once thought. ►

SURVIVAL SKILLS

From predators outwitting their prey to remembering the best watering holes, intelligence can help animals find food and other resources so they can survive and thrive in their environments

TOOL USE

Coordinated hunting helps whales catch fish using bubbles and noise

Using tools was once considered a key capability that set humans apart from other animals in the intelligence stakes. But from otters cracking shellfish open with stones to crows fashioning hooks to dig out worms, we now know that tool use is incredibly widespread in the animal kingdom. And in the Chatham Straits of Alaska, one group of smart humpback whales has taken tool use to another level, catching fish in a way that happens nowhere else on Earth.

Hunting begins when one whale breaches (leaps out of the water). Humpbacks usually travel alone, but this breaching causes nearby humpbacks to form a group. Social groups made up of as many as 15 whales then swim together until, one by one, they disappear in a synchronised deep dive. While one humpback uses its blow hole to produce a wall of bubbles in a wide arc, another whale dives to the sea floor and makes long, high-pitched feeding calls designed to scare herring to the surface.

As the fish rise and the rest of the whales follow the caller, the bubble blower swims closer and closer to the shoal. This creates a very effective feeding tool – a dense bubble net – within which the fish are trapped.

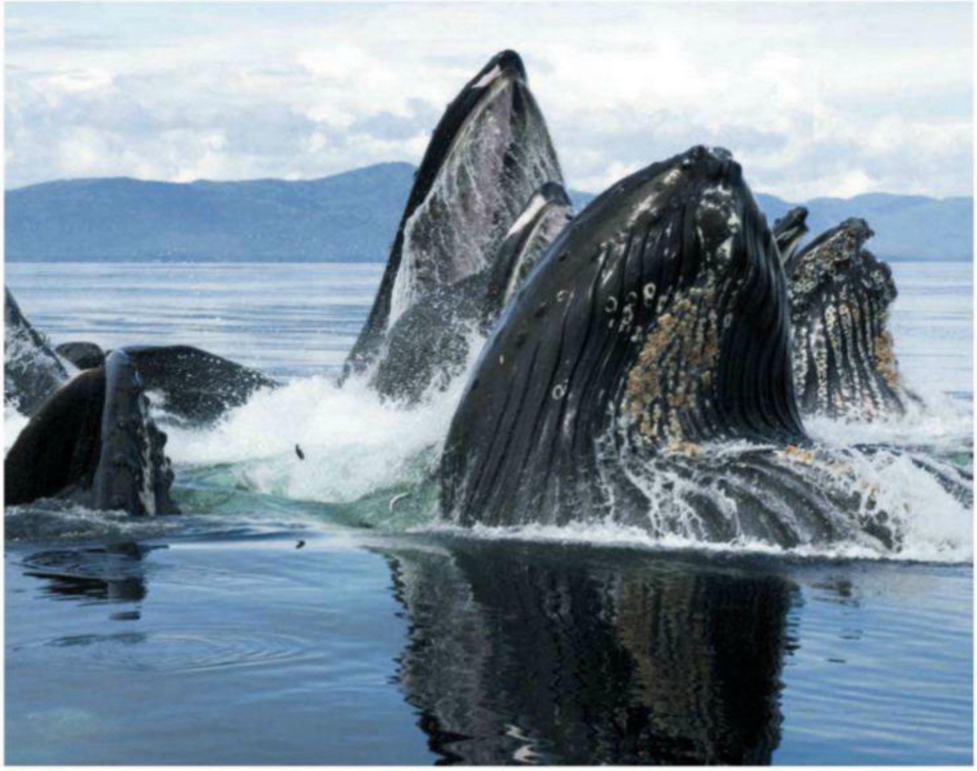
Dr Fred Sharpe of the Alaska Whale Foundation has been studying humpbacks for almost 30 years, and is using hydrophones (underwater microphones) to better understand the nature and function of the feeding call – just one in a complex repertoire of whale calls.

From the still and silent surface, Fred listens in on whale conversations, which give him an indication as to when the whales might reappear. Their calls become more insistent and prolonged, turning into a continuous high-pitched tone. Seconds later the whales emerge looking like giant mussel shells, mouths open to expose their baleen filter as they scoop up the herring jumping at the surface.

Working with the National Geographic Society, Fred has also attached 'crittercams' to the whales, recording video, sound and environmental data in order to observe bubble netting in action from beneath the surface. The stunning footage captured of whales chasing herring to the surface, surrounded by the thick wall of bubbles, has helped Fred further understand this complex hunting behaviour.

Each whale must do its job with absolute precision, keeping track of what others are doing. Tighten the bubble net too soon and not enough fish will be trapped; call at the wrong time and the shoal will escape the net. Successful bubble-netting requires perfect coordination and a large amount of brain power, making this group of humpbacks one of the most impressive tool users on the planet.

Humpbacks form groups to catch fish in a bubble net



BBC, GRANT ATKINSON, GETTY

Liz meets a chickadee who proved smarter than his cousins

ADAPTABILITY

Bird brains can adapt to challenging environments

Biologists at the University of Nevada have shown that animals can become more intelligent as they adapt to challenging environments.

Black-capped chickadees from the harsh climes of Alaska were pitted against those from Kansas in a test to retrieve a worm from beneath a removable glass disc. The Alaskan birds learnt how to lift the glass very quickly, but the Kansas chickadees never solved the problem.

Both groups of chickadees were raised from 10 days old and away from their families, which strongly suggests that birds' cognitive ability to adapt is down to their genetic makeup. Compared with their southern counterparts, Alaskan chickadees also have a larger hippocampus, the region in the brain responsible for memory. This implies that the genes of Alaskan chickadees may have evolved to allow the birds to become better at remembering where they cache resources, a vital skill when food is scarce during the harsh North American winters.

MEMORY

Elephants never forget places they've already visited

In an inhospitable landscape such as the Kalahari Desert, remembering the location of food and water is essential, especially when you need 200 litres of water and 150kg of food per day to survive. They say elephants never forget, and Dr Mike Chase of Elephants Without Borders is amassing compelling evidence that these animals have an exceptional memory for places they may have visited only once in their lifetimes.

From the day an African elephant is born, it begins to store locations of water and food in its memory bank, following the matriarch leading her herd across huge expanses of desert. Mike has attached radio collars to several matriarchs, allowing him to plot the movements of each herd. His data not only reveals that elephants are able to recall places from decades ago, but they also know exactly when the conditions are right to revisit these locations – even if they're huge distances away.

Even more astounding is the fact that elephants seem to be passing on this information from herd to herd, which implies that they must have some means of describing specific places and times of year to each other. For example, thousands of elephants from locations hundreds of miles apart have recently been observed congregating at the Savuti Channel of the Okovango Delta in Botswana, which had been dry for 30 years.

Exactly how African elephant herds share valuable information remains a mystery

To communicate, elephants use infrasound – a 20Hz frequency at the lower limit of human hearing. Infrasound can travel as far as 10km, but science still can't explain how these memory masters, separated by thousands of kilometres, know how to return to one place at the same time.

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SOCIAL SKILLS

Interacting with others in your social group makes life richer and more rewarding. It requires the intellectual capacity to communicate and understand the intentions and emotions of other individuals

COMMUNICATION

Animals express themselves through body language but can learn to use symbols

Panbanisha is a 16-year-old female bonobo, one of eight at the Great Ape Trust in Iowa. She communicates with symbols that represent English words. Having a two-way conversation with Panbanisha involves showing her symbols on boards, although she also understands spoken words.

When I visited Panbanisha to film *Super Smart Animals*, we discussed the surprise I'd bought her and whether we should paint together. She then pointed to the symbol for 'collar', to me, and the symbols for 'open', 'room' and 'car'. Dr Sue Savage-Rumbaugh, a pioneer in bonobo language research, explains that Panbanisha understood the context of the situation: because I was a visitor, she had to put her collar on to go out for a drive (which we did).

Teaching apes to communicate through human language has revealed interesting information, but we could discover much more about the inner workings of animal minds if we could understand how they communicate in their own languages.

The animal kingdom uses vocal and silent communications, but very few people have succeeded in uncovering their meanings. Monty Roberts is one of them. He started studying the language of wild mustangs in the Nevada desert more than 50 years ago, and has discovered that mustangs have a complex body language full of subtle yet meaningful nuances.

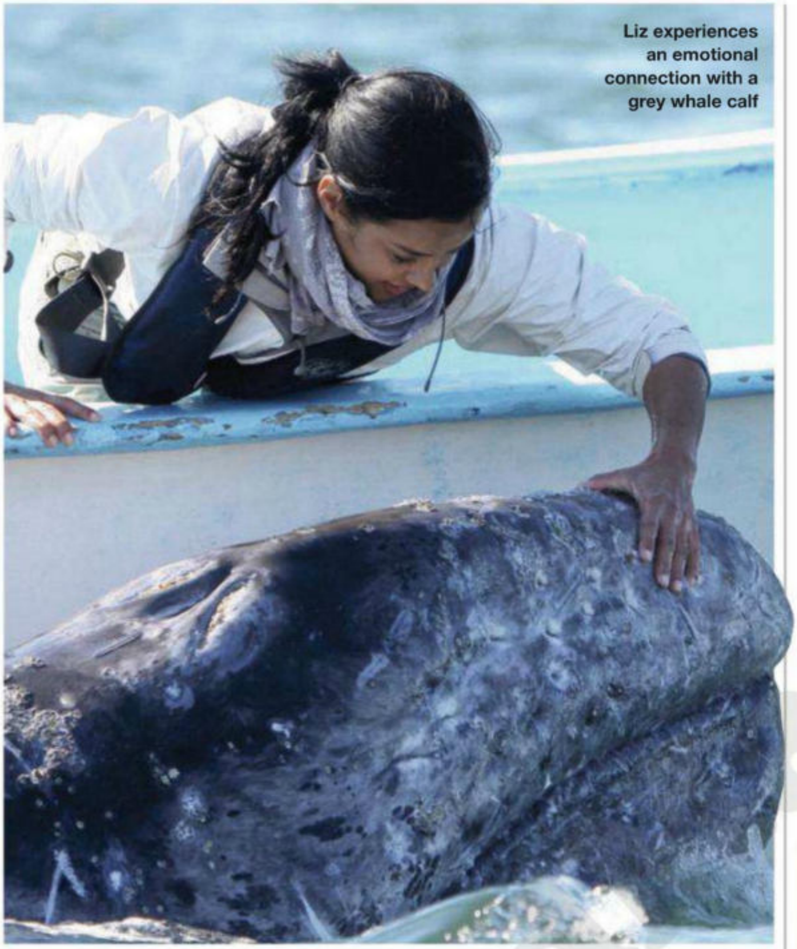
Monty calls this language 'Equus' after the scientific name for horse species. Equus is made up of at least 170 gestures involving the entire body, such as lowering the neck and pinning the ears back in order to 'snake' an ostracised individual out of the herd. Another gesture involves subtly twitching muscles and strategically positioning the eyes, ears and body, or licking and chewing, which bring the horse's adrenaline levels down and signals relaxation. All of these gestures are intricate cues that communicate the horse's state of mind and intentions.

Monty has used heart-rate monitors to demonstrate that these animals also have an incredible innate ability to synchronise their physical and emotional states with those of other animals. This would be an advantage when a predator is prowling nearby, for example, putting the horses into a heightened state of awareness where they would all be ready to run.

Understanding the silent language of mustangs has allowed Monty to 'break' horses in a non-physical way, training them by communicating in their own language. Using a set of gestures to gain a horse's trust, Monty is able to get a horse to choose to come to him. Scientists are now trying to learn the natural language of many other animals to gain insight into how they think, something that we could never achieve by imposing our human language on them.

Panbanisha can understand human words, but we don't speak bonobo yet

BBC, GETTY, GREAT APE TRUST



Liz experiences an emotional connection with a grey whale calf

EMOTIONS

Do whales and birds have feelings?

While we were filming grey whales in Mexico's San Ignacio lagoon for *Super Smart Animals*, 12m-long adults would approach our boat, supporting their calves from underneath so they were close enough for me to touch them. For over an hour, one male calf played, pushing our boat around and repeatedly returning to me to get his belly scratched, and rolling on his side to stare at me for long periods of time.

An experience like this is powerful, convincing you that it is more than a chance encounter. The experience was made even more poignant by the fact that, not so long ago, that very same lagoon was a whaling blood bath, with grey whales charging at boats to protect their young.

Although we can't tell for sure whether whales feel emotions in the same way we do, their brains contain 'spindle cells' – neurones that are responsible for emotions, empathy and self-awareness in humans and apes.

Emotional intelligence is perhaps the most contentious of all animal faculties, and some scientists label all anecdotal accounts of animal emotions as anthropomorphism. But as evidence of sentience accumulates, others argue that science has a duty to investigate the propensity for emotions in the animal kingdom.

Research led by Professor John Marzluff of Washington University in Seattle, for instance, has revealed that crows are able to discriminate between human faces, and that these memories are strengthened by emotion. Brain scans of birds subjected to the masks that John wears while catching the crows show that the amygdala – the fear centre of the brain – becomes activated, establishing that crows feel the emotion of fear.

TEACHING

Meerkats teach their offspring useful life skills

Imparting knowledge to another individual was once thought to be a uniquely human faculty, but several species are proving otherwise. Meerkats, for example, actively teach young how to manipulate dangerous prey.

To study how adults show their offspring how to handle food, researchers at the Kalahari Meerkat Project in South Africa play the recorded begging calls of meerkats from different age groups. When the calls of three to four-week-old pups are played, adults offer harmless invertebrates or dangerous scorpions they've previously disabled by biting off the sting. When hearing 10 to 11-week-olds, however, adults bring more live prey, larger sting-free scorpions, or intact live scorpions that they help the pups disarm.

Along with bees, ants, babblers (a family of birds) and some carnivores, meerkats are thought to be one of only a few species that help make learning easier in this way.

Young meerkats are taught how to handle a scorpion

Super Smart Animals, presented by Liz Bonnin, is on BBC One on 8 and 9 February. Liz also appears in the new series of BBC One's *Bang Goes The Theory* on Monday from 12 March.

FIND OUT MORE

Are you smarter than a chimp? Try to beat Ayumu in a memory test
http://games.lumosity.com/chimp.html

Elephants Without Borders
www.elephantswithoutborders.org

Grey whales on BBC Nature
http://bbc.in/GreyWhale

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MEET YOUR NEXT SMART-PHONE :-)

From cloud apps to curved screens and face recognition... **Daniel Bennett** discovers what we can expect from the next generation of smartphones

Ever since the first smartphones went on sale five years ago, there's been a race to cram as many megapixels and megahertz as possible into something that would still fit in your pocket. The result is that our jackets and trousers are lined with gadgets smarter than computers only a few years old. In fact, devices like Apple's iPhone 4S and Samsung's Galaxy S II rarely use all the computing power at their disposal. But what's next? We scoured the latest patents and interviewed industry experts to find out about the features you'll find in the smartphones of 2014 and beyond. ►

ILLUSTRATION BY MAGICTORCH

THE NEXT GENERATION

Inside the tech that will power your phone in future

The Software

Facial recognition

Pin numbers will soon go the way of the credit card signature. Google's next Nexus handset packs software that allows you to use your mug instead of passcodes to unlock your phone. But a patent filed by Apple hints that you won't even have to press a button for facial recognition to kick in. The screen automatically lights up when you hold the phone to your face.

Cloud apps

While Moore's law predicts mobile phone chips to double in speed and halve in size every year, the cloud represents a huge reservoir of processing oomph that app developers are keen to get their hands on.

"The computing power available through cloud servers is virtually unlimited," says Steve Perlman, CEO and founder of cloud gaming service Onlive. "So once mobile broadband speeds can equal those demands, it'll mean an app's capabilities won't be limited by the phone." Being able to rely on external processing power will make phones smaller and allow for hugely demanding software, such as photo-editing on your phone.

Antivirus

According to David Emm, senior security researcher at Kaspersky Lab, an epidemic of smartphone viruses is imminent.

"The number of purchases people make on their phones will be too tantalising a prospect for cyber criminals to ignore," he says. "Being open source, the Android OS naturally has vulnerabilities. Apple's iOS is more secure, but nothing is perfect. We're already seeing the very early stages of email attacks targeting iOS devices."

Smarter games

What will games look like on your next phone? Mike Capp, president of Epic Games – which was behind the award-winning *Infinity Blade* – says that graphics won't be that important in the future.

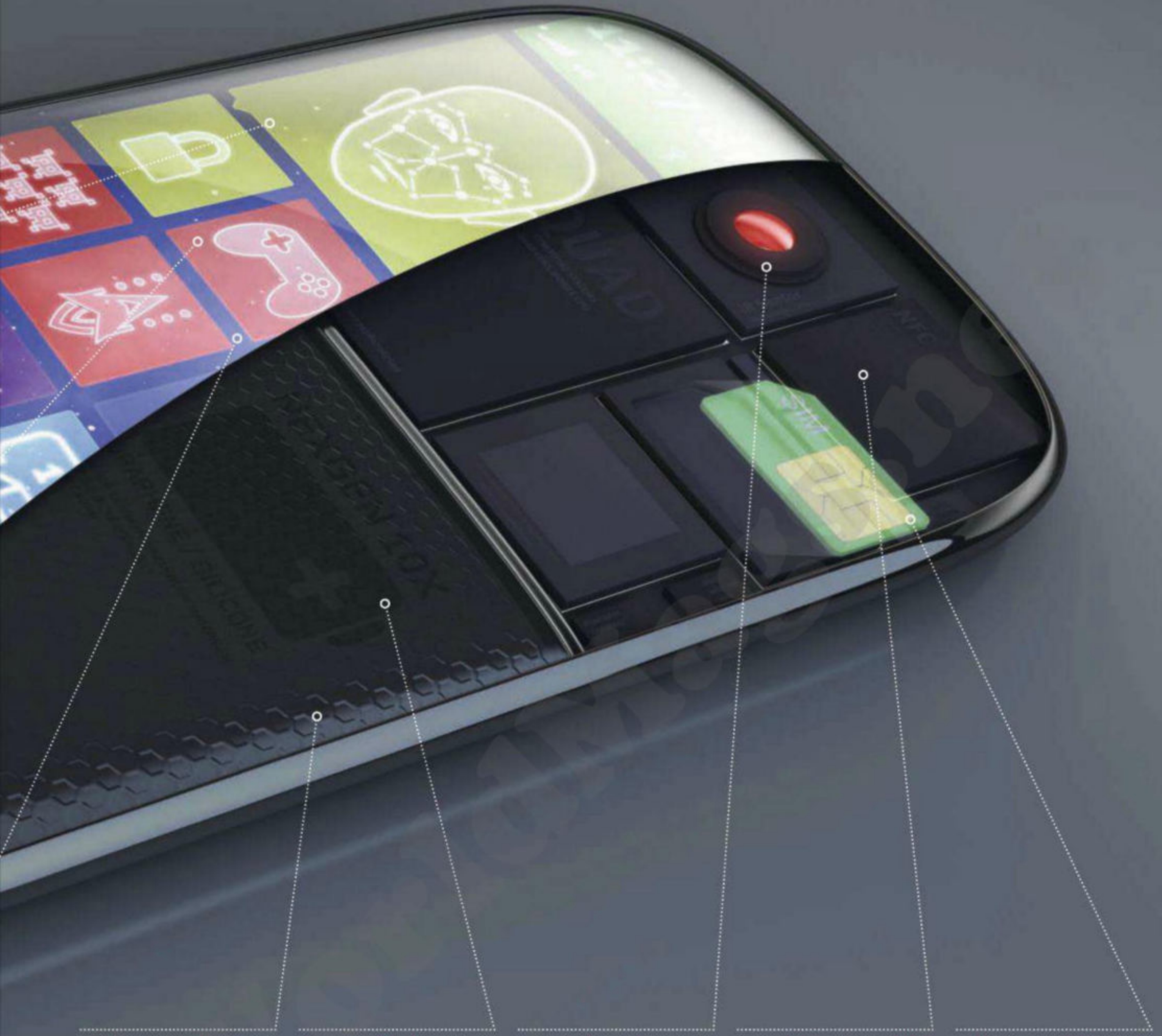
"Being mobile will play a much bigger role – whether it's streaming the game from the cloud or continuing a console game on your phone. You could be sat at a park bench and, using the phone's GPS, you could see anyone playing the same game within a five-mile radius and join in."

The Hardware

Curved screens

We're used to phones looking like flat bricks, but it seems mobile developers want to make handsets with more personality. Leaks from the likes of Nokia, previews of handsets on sale later this year and the fact that Apple has recently built a specialised factory to churn out shaped glass, all suggest that curved screens will be the next big thing. The current trend set by Corning, which makes Gorilla Glass, indicates that by 2015 tougher glass will allow for screens that could be 50 per cent thinner.

ILLUSTRATION BY MAGICTORCH



Waterproof coating

Hotly-tipped new company HzO has developed a coating that would make electronic components immune to water damage. While it doesn't prevent liquid touching the circuitry, it does make anything that gets through harmless. "We've only tested it as far as one metre deep," says Rick Peterson, the marketing director of HzO, "but our initial results have got a number of companies interested. If all goes well we could be using this coating on phones in two or three years."

Longer-life batteries

A team of chemical engineers at Northwestern University, Illinois have created a lithium ion battery that would endure a week's use and recharge in 15 minutes. It uses an anode – the part that delivers electricity into the battery – made out of a graphene/silicon sandwich. This delivers more electricity into the battery in less time. Lead researcher Dr Harold Kung says this tech could make its way into mobile phones, laptops and tablets within the next three years.

Infrared camera

Your next phone's camera won't just capture more megapixels. In December, Apple was granted a patent for an infrared (IR) receiver attachment. The idea is that a railway station, for example, would have a corresponding device to broadcast train timetables to your phone. This info would then be overlaid on your camera's live view, showing you when the next train's due to leave. On the downside, music venues could send out a signal that would stop people filming concerts with iPhones.

Ubiquitous NFC

Near Field Communication (NFC) makes connecting your phone to a speaker, for example, as easy as tapping your handset on your stereo. When two NFC-enabled devices get close, they recognise each other and connect via Bluetooth. The whole system can be automated, so that your phone would automatically sync when it's positioned next to your PC. Once shops adopt NFC receivers – as ticket machines on London's Tube already have – you'll be able to make one-touch payments with your phone.

No more SIM cards

In pursuit of a supermodel-thin smartphone, Apple is on the march to remove SIM cards from its handsets altogether. A SIM reader takes up a lot of space, so the company filed a patent in November for a virtual replacement. The iPhone is digitally allocated to a network on purchase. One benefit is that the freed-up space could be filled by hardware: an NFC router that would share its internet connection with a laptop or a tablet when such a device gets near enough to the phone. ▶

AND IF YOU'RE AFTER SOMETHING MORE FUTURISTIC...

Here's what the smartphone will look like a decade from now

Skip
16:39
Fridge says: John, you're out of milk, you're about to pass the supermarket so you should pick some up
Shuffle
caps lock

The Hardware

Flexible screens

Since most smartphones are all screen and not much else, they have a nasty tendency to shatter when dropped. So both Samsung and Nokia have been working on a novel fix. Instead of making the glass shatterproof, both companies believe that flexible AMOLED technology is the way forward. Since the screen material is malleable, it's able to withstand harsh impacts. *Focus* was shown a demo this year where working screens withstood hammer blows, with only slight scratches for damage. Further down the line, Nokia hopes that bending and twisting the phone will be an extra input method – bending a corner could skip a music track, for example.

Pico projectors

Even the best touchscreen keyboards can be frustrating at times. While watching the TV series *Sherlock* on your mobile is convenient for train journeys, the screen is too small for home entertainment. The solution lies with a built-in projector. CTX Technologies let us play with its working prototype, which projects a virtual laser keyboard from its base and an 80-inch screen from the top. The prototype certainly wasn't pocket-friendly, but the company's CEO Clifford M Rhee says it's been working on a phone and tablet equivalent that could hit shops in five years.

Super thin

Graphene: it's one atom thick, transparent and superstrong. Nokia is teaming up with the Nobel laureates that discovered this miracle material to develop a truly different future generation of smartphones. Nokia has drawn up a concept device based on graphene components that would be thin enough to give you a paper cut, and flexible enough to fold away into your pocket. Sadly, the first graphene parts that can be mass-produced are yet to be built, so it'll be a good few years before the dream becomes a reality.

The Software

Artificial intelligence

Right now Siri, Apple's 'digital assistant', is only smart enough to help you put an entry in your diary. But as mobile phones' net connections improve they'll be able to leave more data crunching in the hands of cloud servers, allowing for devices that are not just smart, but actually intuitive.

"Speech recognition algorithms are very data-hungry" says Vlad Sejnoha of Nuance, the company that helped develop Siri. "With better connections available, more data can be interpreted and more instructions can be understood." So your phone should become more like a personal assistant than a partially-deaf butler.

Globally connected

It's not just phones that will be smarter. TVs, washing machines and even fridges are shipping with computer processors. According to tech industry analysts Gartner, this is all leading to the creation of an 'internet of things'. So your fridge could send you a text message when you run out of milk. Looking further into the future, most of the devices in your home are likely to be linked in some way to your smartphone. ■

Daniel Bennett is reviews editor of Focus *magazine*

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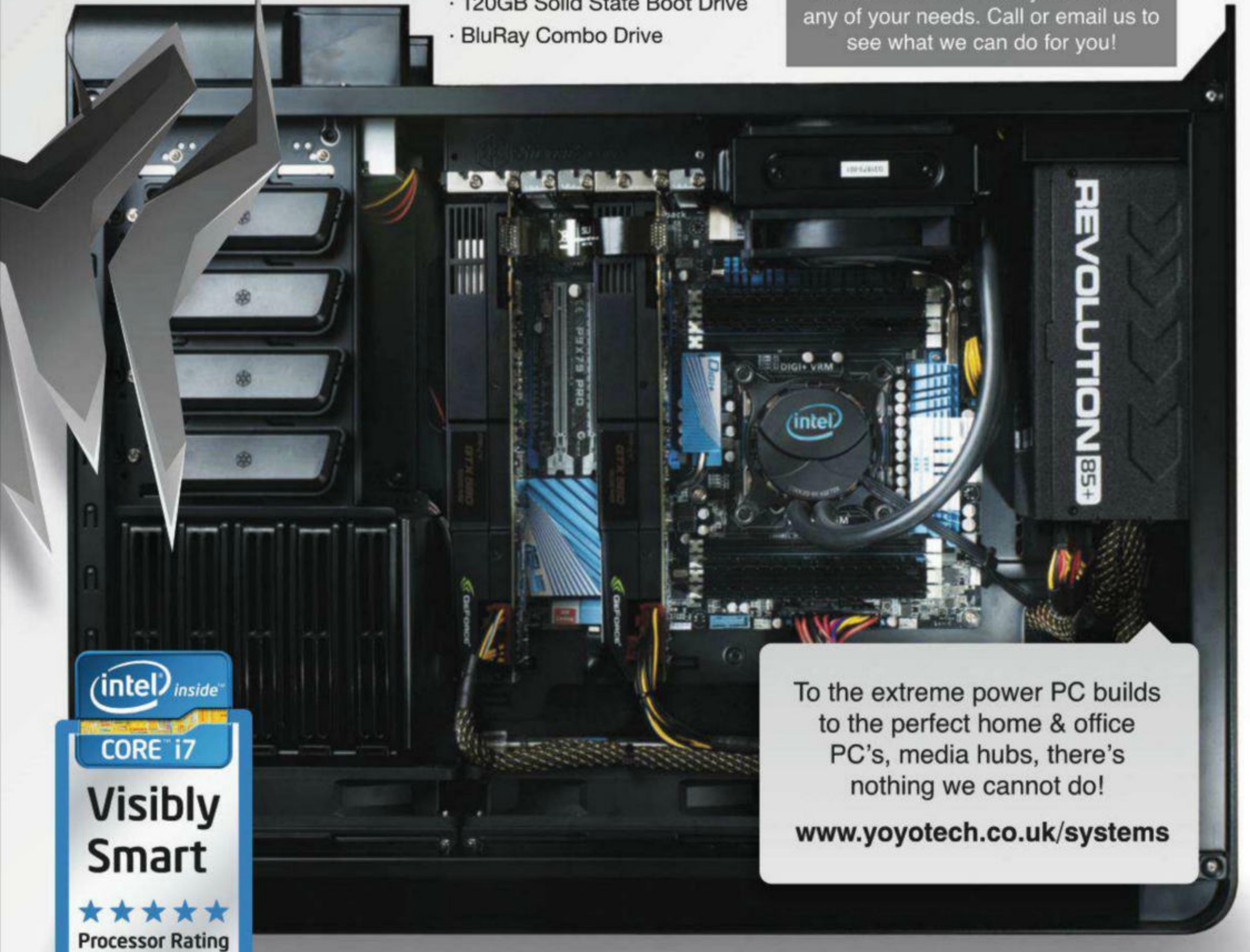

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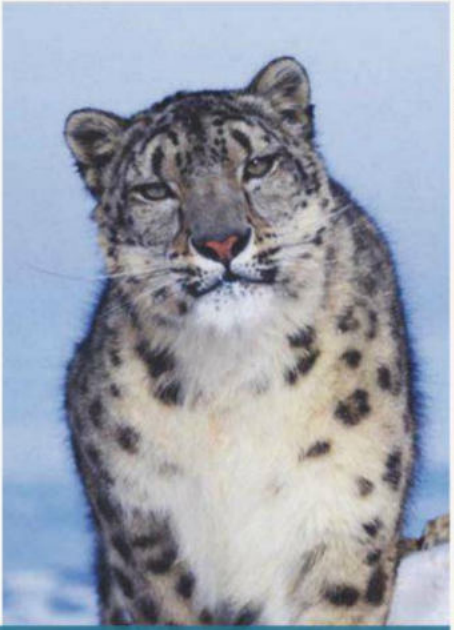

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Climate change's NASTY SECRET

Global warming evokes images of scorched crops and rising sea levels. But, says **Professor Bill McGuire**, it can also alter the behaviour of planet Earth itself

We're all familiar with headlines predicting the consequences of climate change – extreme weather, floods and extinctions. But it is becoming increasingly clear from recent research that when the climate undergoes dramatic changes, the solid Earth gets involved too. Like a slumbering giant repeatedly prodded with a stick, what geologists call the geosphere – the outer part of the Earth – tosses and turns in response to drastic shifts in the climate, spawning earthquakes, driving tsunamis and even provoking a lively response from the Earth's volcanoes.

The driver for this surprising and often overlooked reaction is one of the commonest substances on the planet – water. Over the past couple of million years, the global distribution of water has undergone huge changes as our world has switched from icehouse to hothouse on around 50 occasions. Stupendous volumes of the stuff have been repeatedly locked up in giant ice sheets at high latitudes when the planet has cooled and decanted back into the ocean basins when temperatures have risen again. Water is heavy, and there's lots of it. ►

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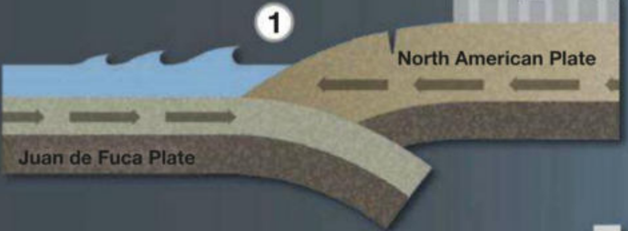
Geological hotspots

Rising temperatures could prompt a reaction from the Earth around the globe

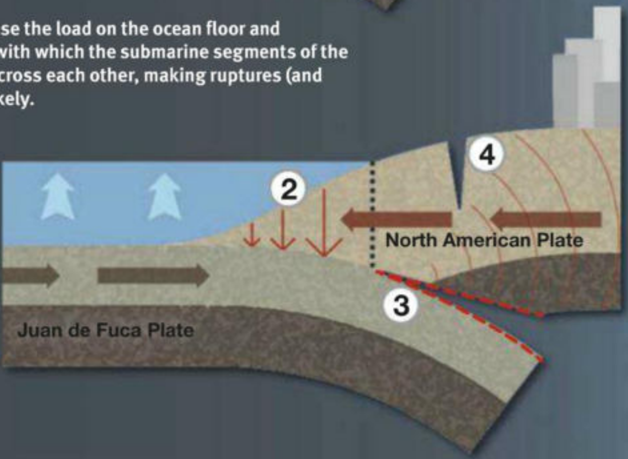
A shifting threat

As the sea level rises due to climate change, the most likely location of earthquakes shifts



① When one tectonic plate moves against the other under the ocean, water is displaced causing a tsunami.

② Rising sea levels increase the load on the ocean floor and therefore reduce the ease with which the submarine segments of the tectonic plates can move across each other, making ruptures (and therefore tsunamis) less likely.



③ With a higher sea level, the part of the subduction fault under the ocean now has much more weight bearing down on it than the part which isn't. This reduces the friction between the tectonic plates in the part of the fault beneath land, increasing the earthquake threat to coastal cities.

④ Away from the Cascadia subduction zone, a different process will be at play. As sea levels rise, the Earth's crust bends in such a way that it 'unclamps' faults that run parallel with the coast, such as California's San Andreas Fault. The reduction in friction makes 'quakes more likely.

North America's west coast
A rapid rise in the sea level may promote earthquakes on the landward part of the Cascadia subduction zone fault, increasing the threat to Seattle and Vancouver.

Central America and the Caribbean
Wetter tropical storms and cyclones would lead to more intense rainfall on the volcanoes of Central America and the Caribbean. This may destabilise slopes, leading to destructive mudflows and even more eruptions.

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▶ So much, in fact, that the total weight of the world's surface water adds up to an unimaginable number of tonnes – something like 1.35 followed by 16 zeros. Every time our planet has flipped from the frigid cold of an ice age to warmer conditions and back, about four per cent of this mass has shifted between the icy poles and the oceans – easily enough to stimulate a vigorous response from the solid Earth.

With the great ice sheets at the top and bottom of the world currently melting and breaking up fast, and sea levels climbing remorselessly, the big worry that hasn't hit the headlines is that human-induced climate change is encouraging the slumbering giant beneath our feet to stir. As a consequence we could be bequeathing to our children and their children not only a far hotter world, but also a more geologically unstable one.

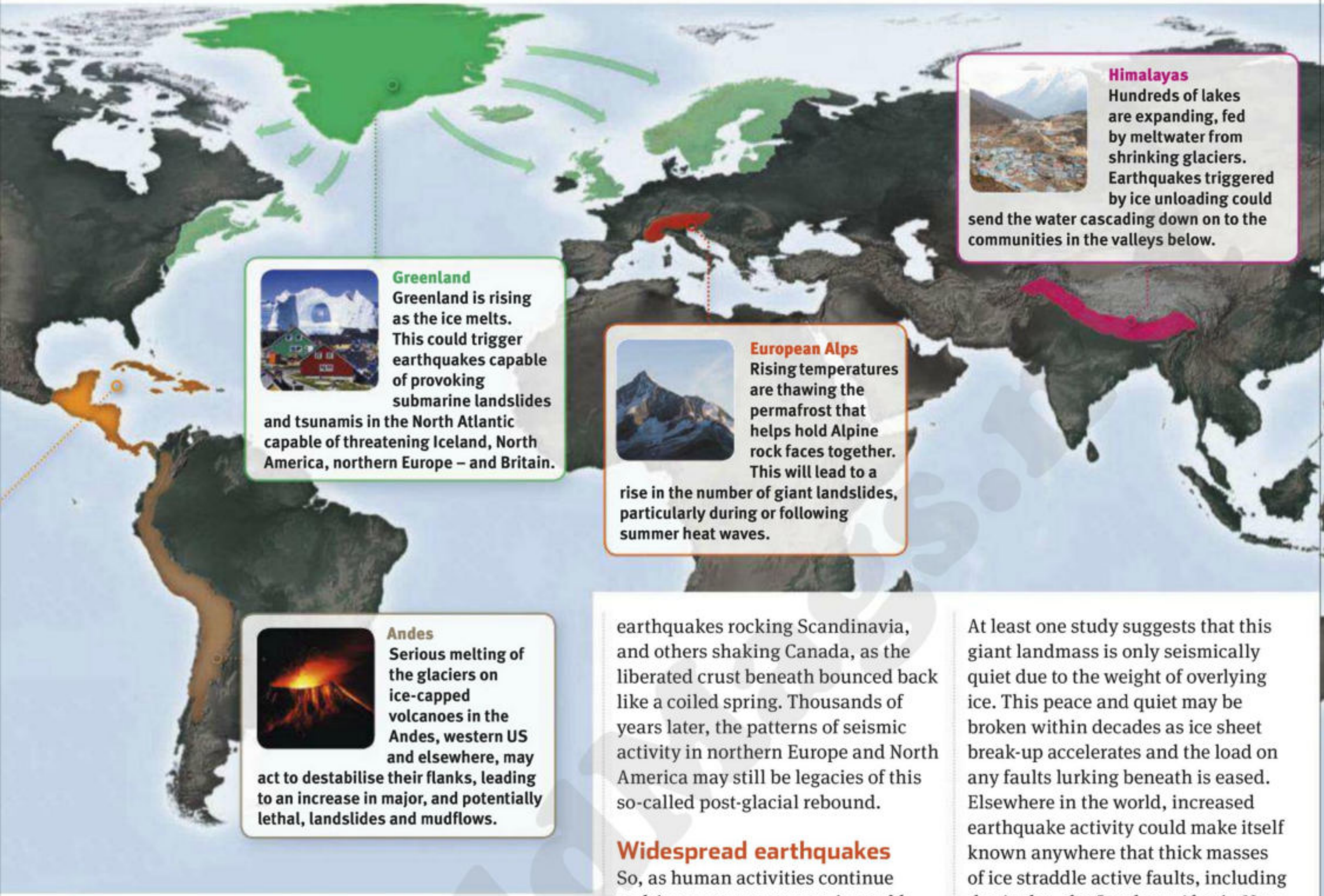
Alaska's glaciers have played a role in suppressing earthquake activity

Warning signs

Such is the level of concern that, for the first time, the Intergovernmental Panel on Climate Change (IPCC) addressed the issue of climate change driving a geological reaction in its 2011 report on extreme events. One real anxiety is that, provided a fault is critically poised to rupture, or a volcano ready to blow, or an unstable mass of rock ready to slide, it seems that just a small nudge may push it over the edge.

Despite global average temperatures having only climbed by about 0.8°C since 1900, we are already getting the first inklings that warming has started to provide this nudge.

Hardly surprisingly, these early signs are being detected at high latitudes, most notably in Alaska. This US state is proving to be something of a canary in the cage due to the coincidence of melting ice and plenty of active faults. It provides opportunities for interaction between



Greenland
Greenland is rising as the ice melts. This could trigger earthquakes capable of provoking submarine landslides and tsunamis in the North Atlantic capable of threatening Iceland, North America, northern Europe – and Britain.

European Alps
Rising temperatures are thawing the permafrost that helps hold Alpine rock faces together. This will lead to a rise in the number of giant landslides, particularly during or following summer heat waves.

Himalayas
Hundreds of lakes are expanding, fed by meltwater from shrinking glaciers. Earthquakes triggered by ice unloading could send the water cascading down on to the communities in the valleys below.

Andes
Serious melting of the glaciers on ice-capped volcanoes in the Andes, western US and elsewhere, may act to destabilise their flanks, leading to an increase in major, and potentially lethal, landslides and mudflows.

the two as the local climate continues to warm up considerably faster than the Earth as a whole.

The enormous weight of ice contained in Alaska's glaciers has played a role in suppressing earthquake activity, simply by loading the faults below and making it more difficult for them to move. Recently, however, the speed of ice loss has been astounding – the Bagley Ice Field in the south of the state, for example, has lost up to 1km (0.6 miles) in thickness since the early 20th century. As the ice has wasted away, so the reduced load has freed up the faults below, allowing them to move more easily and leading to a rise in the number of small earthquakes.

Looking back, exactly the same response followed the retreat of the great ice sheets that covered much of northern Europe, North America and northern Asia little more than 10,000 years ago. Their disappearance promoted huge, magnitude 8 earthquakes rocking Scandinavia, and others shaking Canada, as the liberated crust beneath bounced back like a coiled spring. Thousands of years later, the patterns of seismic activity in northern Europe and North America may still be legacies of this so-called post-glacial rebound.

Widespread earthquakes

So, as human activities continue to drive up temperatures, it would not be at all surprising to see a hike in earthquake activity beyond the Alaskan state borders. At the Earth's polar regions, in particular, melting of the enormous thicknesses of Arctic and Antarctic ice is already beginning to release the crust beneath, with Greenland now bouncing back up at a rate of a couple of centimetres a year. At least one study suggests that this giant landmass is only seismically quiet due to the weight of overlying ice. This peace and quiet may be broken within decades as ice sheet break-up accelerates and the load on any faults lurking beneath is eased. Elsewhere in the world, increased earthquake activity could make itself known anywhere that thick masses of ice straddle active faults, including the Andes, the Southern Alps in New Zealand and the Himalayas.

Regions far distant from any ice fields may also be at risk if we see really serious rates of sea-level rise in the coming century and beyond. However, there may be some good news. As the ocean basins fill, the added load of the extra water will stabilise subduction zone faults ▸

Avalanches like this are happening more frequently in Alaska

Tiny changes, big effects

Seemingly minor climatic events can stir up geological mayhem

Wind driven volcano

Eruptions at Alaska's Pavlof volcano tend to occur from September to December. The underlying cause seems to be a less than 20cm seasonal rise in the level of the northern Pacific Ocean during autumn and winter, caused by changing wind patterns pushing extra water into the area. The extra weight of the added sea water adjacent to this coastal volcano is just sufficient to bend the crust beneath and this squeezes magma up and out like toothpaste from a tube.

Landslide under pressure

Even relatively small changes in atmospheric pressure have been known to cause landslides. The atmosphere demonstrates daily variations in pressure, or 'tides' driven by the heating effect of the Sun. In the San Juan Mountains of Colorado there's a 170 million cubic metre, slow-moving flow of debris called the Slumgullion landslide. Times of slippage correlate with daily atmospheric tidal lows – reduced pressure apparently promoting easier movement.

Earthquakes from typhoons

Earthquakes are caused by sudden movements along faults in the Earth's crust, but faults can move quietly, generating 'silent' or 'slow' earthquakes. In eastern Taiwan, the occurrence of such slow quakes has been linked to typhoons. The sharp fall in air pressure as the core of a storm reaches their vicinity allows faults beneath to unclamp and move more easily. As slow earthquakes may be capable of triggering bigger ones, this is an important relationship.

Snow-generated shakes

The idea that there could be a link between snowfall and earthquakes sounds far-fetched. Nevertheless, the timing of quite large – more than magnitude 7 – quakes in the inland mountains of Japan has been associated with snow. A study of past records shows that earthquakes here tend to occur in the spring; the idea being that melting of the thick cover of winter snow reduces the pressure on shallow faults by just enough to promote their rupture.

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► beneath the oceans. At these faults, one tectonic plate plunges beneath another and shifts can generate catastrophic tsunamis. The bad news is that the same effect looks likely to encourage earthquakes on these faults closer to coastal cities, with potentially devastating results. (See 'A shifting threat' on page 62).

It should come as no shock to hear that climate change is already bringing about an increase in landslide activity, as the ice and permafrost that hold many of the world's mountain faces together thaws. Once again, Alaska is at the heart of the action, with huge rock and ice avalanches occurring far more frequently on some of the state's most notable peaks.

British tsunamis

Around margins of the North Atlantic, the future landslide threat may actually come from below sea level

The steaming aftermath of Iceland's Grimsvötn volcanic eruption in 2011

Greenland's rise could trigger tsunamis like this one in Japan

The tsunami was 25m (80ft) high when it struck the Shetland Islands

rather than above. Earthquakes spawned as a result of Greenland's resurgence might trigger submarine landslides around the edge of the North Atlantic that are capable of sending tsunamis barrelling into the coasts of Iceland, eastern North America, northern Europe – and Britain.

This wouldn't be without precedent. Around 7,000 years ago, seismic shaking linked to the post-glacial uplift of Scandinavia sent a colossal pile of sediment careering down the continental slope off Norway's west coast. The resulting tsunami was 25m (roughly 80ft) high when it struck the Shetland Islands and still up to 6m (roughly 20ft) high when it flooded the North Sea coasts of Scotland and northern England.

So, more earthquakes and more landslides, but what about volcanoes? Will a warmer Earth be a more fiery one too? Quite possibly. In Iceland, the Vatnajökull ice cap in the south east is wasting away and the crust beneath popping up as a result. The shrinking glacier covers the Eyjafjallajökull and Grimsvötn volcanoes, whose recent eruptions caused severe disruption to air traffic.

Recent modelling studies forecast that as the shrinkage continues to diminish the load on the hot rocks beneath, more of them will melt and enough magma will ultimately be created to feed three more moderate eruptions every century. That's three more than Iceland's population, and the aviation industry, need.

Volcanoes in Alaska, Russia's Kamchatka Peninsula, western North America, the Andes and New Zealand also have diminishing ice cover. Here, the removal of buttressing ice may be all that is needed to encourage collapse of the flanks, producing giant landslides. What's more, infiltrating meltwater may come into contact with hot magma lurking within – always an explosive mixture.

Volcanoes at lower altitudes and in warmer climes are also not immune to the effects of human-driven climate change. More than half of our world's 1,500 or so active volcanoes either form islands or are located on the coast. As such, they are susceptible to any changes in the stress accompanying bending of the ocean margins as meltwater continues to push up sea levels. As Alaska's Pavlof volcano ably demonstrates (see 'Tiny changes, big effects', on opposite page), it doesn't take much, in such circumstances, to light the blue touch paper.

While it has to be said that the picture being painted is pretty dismal overall, there does seem to be a bit of straw to be clutched at. Maybe, if climate change triggers a few big explosive eruptions over a short period of time, the resulting sulphur gases pumped into the atmosphere would cool the planet, these gases being efficient at absorbing incoming solar radiation or reflecting it back into space. Sadly, as the gases are only likely to hang around in the atmosphere for a few years, any respite they provide would be brief. By that stage, any volcanic response – short of a cataclysmic super-eruption – would be far too little, far too late. ■

Bill McGuire is Professor of Geophysical and Climate Hazards at University College London

FIND OUT MORE

http://ipcc-wg2.gov/SREX/
IPCC report which looks at the impact of global warming on climate change

Waking The Giant: how a changing climate triggers earthquakes, tsunamis and volcanoes **by Bill McGuire (Oxford University Press) goes on sale on 23 February 2012**

How to rewire your mind

Professor Richard Davidson says we have the power to physically alter our brains by transforming the way we think. He tells **Andy Ridgway** how to perform brain surgery

Your new book revolves around the idea that each of us has our own set of emotional 'styles'. What do you mean by that?

There are six emotional styles. You can think of them as a constellation or set of factors that result in the overall way each of us responds to emotional challenges.

Can you explain these six styles?

They derive directly from 30 years of neuroscience research. The first is resilience style. This deals with the rapidity with which you recover from a negative event. Some people respond quickly, while others show a persistence of negative emotions for long periods.

The second is outlook style. It's the flipside of resistance and is your capacity to retain a positive emotion following a positive event. If you have a wonderful conversation with your spouse in the morning, for example, are you in a positive mood for the rest of the day, or does that positive glow wear off quickly?

Third is social intuition style and refers to your skill at detecting the social cues of others. Some people can detect subtle changes in facial expressions, body posture or tone of voice. Others are clueless.

Next is self-awareness style, which focuses on your capacity to know what's going on inside your body. Some people are really good at detecting their own emotions by noticing things like their heart beat and muscle tension, while others aren't so tuned into their bodies.

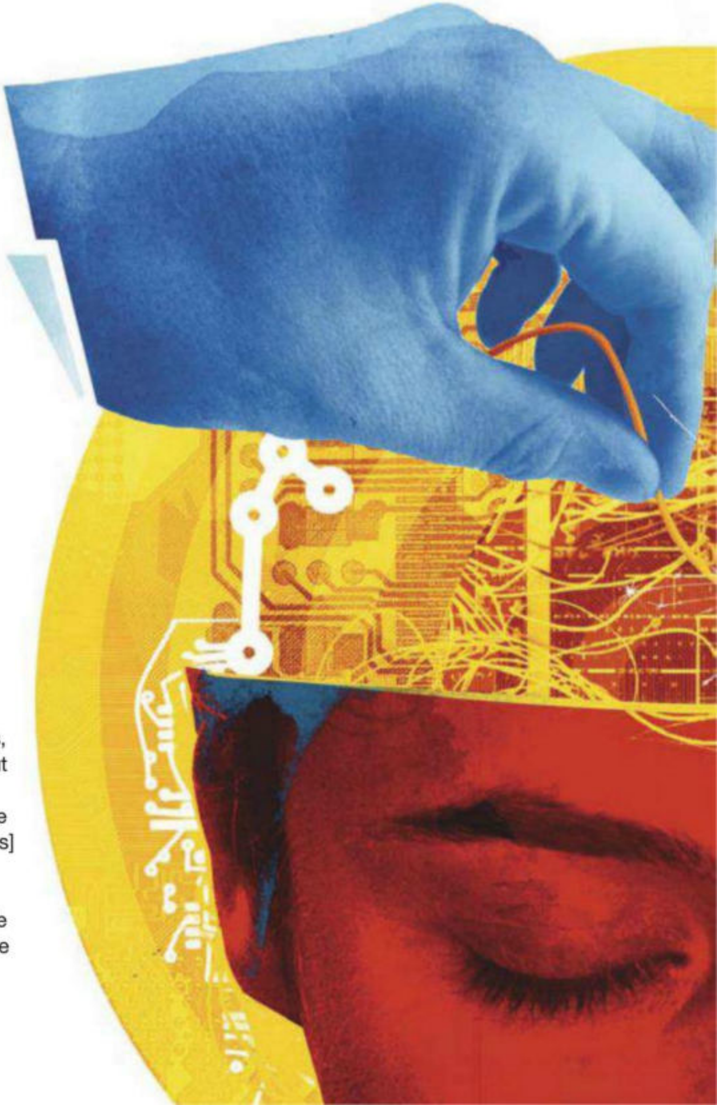
The sensitivity-to-context style is the fifth and refers to how responsive you are to the environment you find yourself in. Your emotional responses when you're with your boss, for example, should be different to when you're with your spouse. Finally, attention style is the sixth and is your capacity to focus your attention.

How has neuroscience led you to define these styles?

Each style comes from a specific body of research that has identified brain circuits that underlie it. With the resilience style, we know that links between the prefrontal cortex [implicated in decision making and moderating social behaviour] and the amygdala, which is an important area for the generation of emotion, are critically important for regulating the responses to adversity. So a person who displays resilience has stronger connections between the prefrontal cortex and the amygdala. They can moderate the responses in their amygdala better.

What do you mean by stronger connections?

We can't say there are more nerve cells, or neurons, connecting these areas. But there may be more links between the neurons within these connections, more myelination [coating around the neurons] in the links and their axons – the elongated part of the nerve cell – may be larger in diameter. From the available evidence, we don't know which of these mechanisms operates. There could be more than one.



JEFF MILLER, ILLUSTRATION BY ANDY POTTS

What factors determine someone's emotional style?
We come into the world with some genetic propensity to respond to challenges in certain ways. But we also know that environmental circumstances play an important role.

Can you change your style?
Yes, there are all kinds of ways of changing it. They range from taking medication that we know alters neurochemistry, to engaging in certain kinds of mental exercises or behavioural strategies that transform the mind. Through these we can change the brain.

So if you do the mental exercises, you can physically change your brain?
Yes, there's clear evidence. Physical changes have been detected in subjects after they have undertaken as little as two months' training.

Say you find social situations, such as parties, difficult. Can training change the way you react?
The responses – such as an increase in heart rate and sweating – are produced because, for whatever reason, the exposure to unfamiliar people in this context is seen as threatening.

Resilience is an issue here. The initial discomfort can't be turned off easily but one of the things you can do is to be non-judgemental. So rather than seeing unfamiliar people as threats, they're simply unfamiliar people. But that's something that requires practice – you can't just read something and expect to embody it. It's a kind of learning: learning to perceive your environment in a non-judgemental way.

You can also change your relationship with what's going on inside your body, so you become much more aware of the changes in muscle tension and heart rate, but without reacting to them. Rather than interpreting the changes as a sign of anxiety or panic, you simply notice them. Again this means being non-judgemental. Learning to pay attention non-judgementally is referred to as mindfulness training.

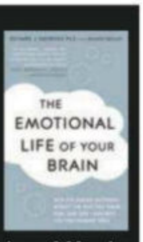
> *"There is now abundant research indicating there are behavioural and neural changes that can be brought about through meditative training"*

By being non-judgemental, what part of your brain are you influencing?
When you interpret something as a threat, it's often self-focused. You think, 'This is something that's threatening to *me*.' But if you reframe these things more objectively – this is an unfamiliar person or this is a heart that's beating faster – you begin to de-identify with it.

There's a network in the brain associated with self-focused processing, the medial prefrontal cortex. When we still perceive these things but don't see them in such a self-focused way, it's expressed in the brain as a decreased connection between the medial prefrontal cortex and other regions.

What if you have difficulty concentrating on tasks?
That's one that really has been addressed by mindfulness meditation exercises. They involve, for example, focusing on your breathing – on the sensation in your abdomen as you breathe or the tip of your nostrils as air goes in and out. That's an effective method for training attention. There's now abundant research indicating that there are behavioural and neural changes that can be brought about through that kind of meditative training.

Is there an 'optimal setting' for each emotional style?
The optimal place in each style varies for each person. One formula doesn't fit all because people exist in different environments. ■



Richard Davidson is the Vilas Professor of Psychology and Psychiatry at the University of Wisconsin-Madison. *The Emotional Life Of Your Brain* by Professor Davidson and Sharon Begley (Hodder & Stoughton, £13.99) is on sale on 9 March

SAVING SPECIES

DNA sequencing is enabling biologists to test the genetic health of species such as the short-haired bumblebee. **Henry Nicholls** asks if the genomic revolution can help conservation practice

Coming soon to BBC Radio 4: the new series of *The Living World*

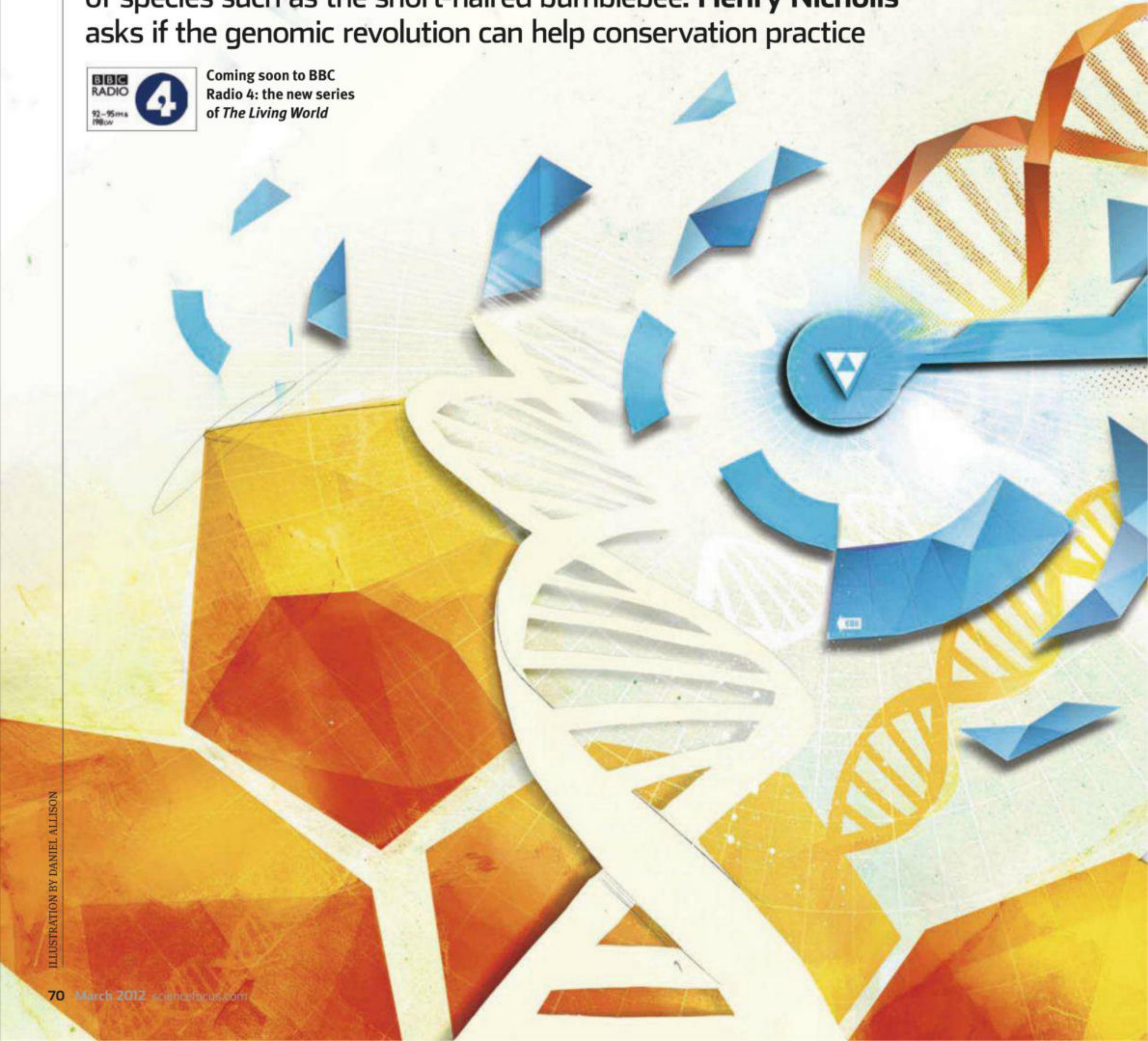
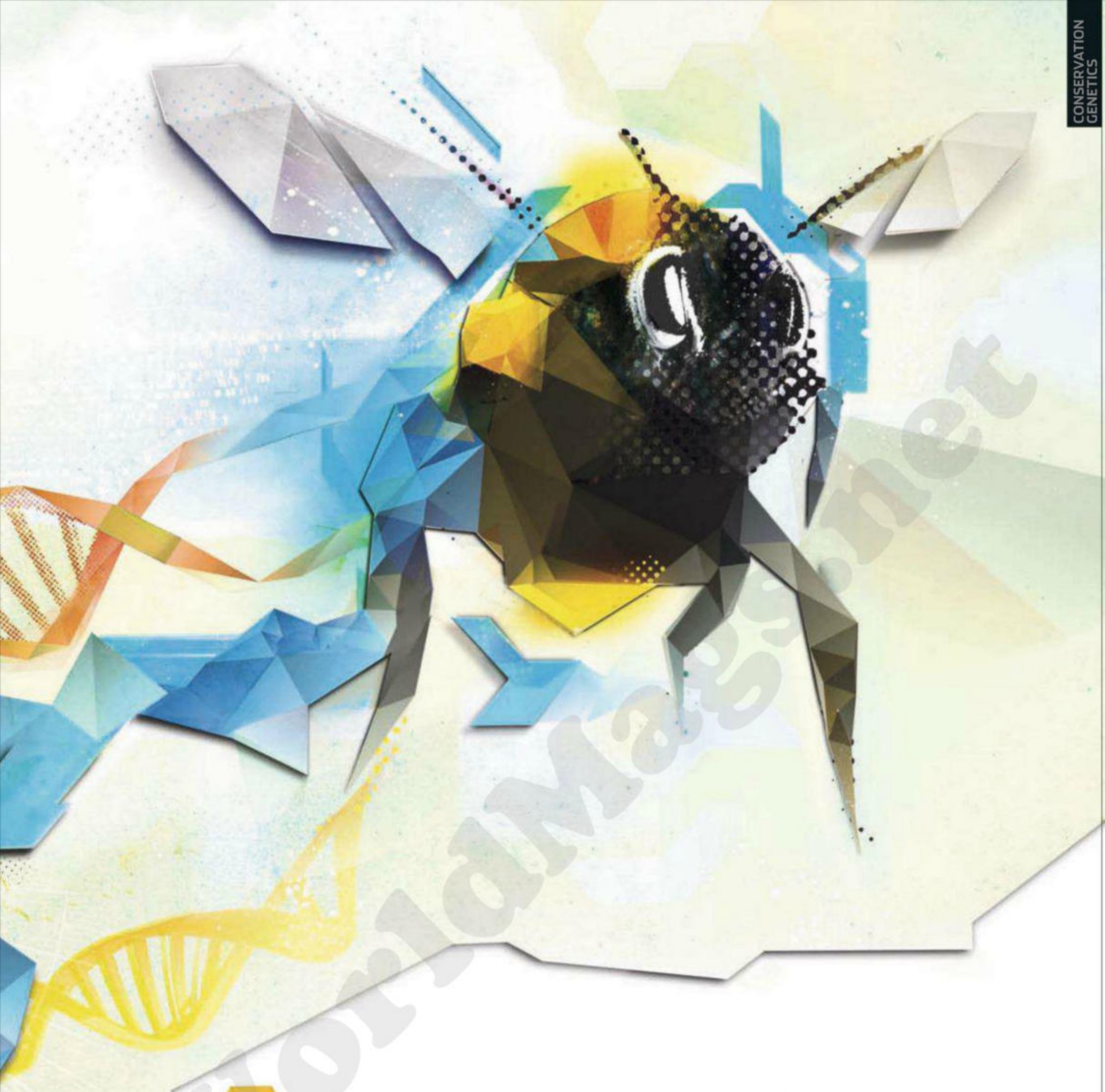


ILLUSTRATION BY DANIEL ALLISON



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The hedgerows of Britain are just a little quieter than they should be. The gentle hum of the short-haired bumblebee *Bombus subterraneous* has not been heard within these shores since 1988. But come spring, conservationists will release more than 50 queens back into the Kent countryside.

These buzzing pioneers were due to come all the way back from a population established in New Zealand by 19th-century settlers. At least that was the plan, until genetic tests revealed the Kiwi bees may be descended from just two individuals – a population bottleneck that will have reduced the variation in the gene pool and would potentially make the bee less able to adapt to environmental change. Worried about the bees' genetic health, the conservationists are now looking to Sweden as an alternative source of queens.

This is a classic example of 'conservation genetics', the use of DNA and ultimately entire genomes to improve conservation practice. "Genomics gives us more information and allows us to make difficult decisions from a more informed perspective," says Professor Fred Allendorf, a conservation geneticist at the University of Montana.

For more than two decades, biologists have been using DNA's barcode-like qualities to help identify organisms, revealing the genetic health and fitness of a population or species. Genetics can be used to infer historical events like the bottleneck experienced by New Zealand's short-haired bee population.

In recent years, advances in sequencing know-how have opened the floodgates to a deluge of data flowing into genetic databases. In theory, these vast online resources could be a powerful tool for conservation practitioners, helping them to weigh up the pros and cons of adopting a particular intervention.

Professor Robert Wayne, an evolutionary biologist at the ▶

▶ University of California, Los Angeles, was one of the first to explore what this wealth of DNA data might mean for conservation.

Until recently, researchers such as Wayne could only test the genetic health of an animal population by sampling what's sometimes dismissed as 'junk DNA' – that is, repetitive sequences of DNA that don't include the genes that encode proteins and whose function (if they indeed have one) remains a mystery. Junk DNA dominates the genome, and sampling a handful can provide a reasonable reflection of a population's overall genetic variation, a measure of its genetic health.

But there have been instances where sampling junk DNA has led to mistaken conclusions, with significant consequences for conservation, such as in the case of rare foxes on the Channel Islands of California. In the 1980s, Wayne noticed that from a genetic perspective, foxes from the island of San Nicolas looked like perfect clones. There appeared to be no genetic variation between individuals, suggesting that the San Nicolas Fox was perilously inbred.

After the dog genome was sequenced in 2004, however, Wayne was able to use the sequence as a guide to probe the fox DNA for sequences known to be important for survival, and found islands of surprising genetic diversity surrounded by a sea of identical sequences. It seems the foxes of San Nicolas weren't in such a tight fix after all, suggesting that genetic variation at these islands and other key sites in the genome might be the key to the long-term survival of endangered populations.

Wayne, who has had a lifelong interest in the conservation of wild canids (relatives of dogs), gives a more alarming example of the perils of making conservation decisions without enough DNA data. Since the 1980s, black wolves have been sighted

LEARNING FROM EXTINCTION

Studying DNA of lost animals such as the woolly mammoth could help conservation now

A member of Stephen Schuster's lab prepares DNA samples from a woolly mammoth for sequencing

Extinct animals such as the woolly mammoth may only be footnotes in evolutionary history, but looking at fragments of their DNA could help in the conservation of those creatures that are with us still. In 2008, the journal *Nature* published the complete DNA sequence of the woolly mammoth, the first extinct species to have its genome sequenced. Since then other extinct creatures, such as the Thylacine (Tasmanian tiger), have followed suit.

Stephan Schuster, a geneticist at Pennsylvania State University, is the driving force behind the sequencing of the mammoth genome. He believes that DNA extracted from the remains of these extinct wonders will give an entirely new perspective on how past diseases, invasive species, hunting pressure and climate change affect the genetic architecture of the species. Ancient DNA from hundreds (if not thousands) of specimens spanning tens of thousands of years would reveal what happened to the mammoth genome as the climate warmed towards the end of the last ice age. The heat not only changed the mammoths' habitat but also allowed our ancestors to hunt them with increasing enthusiasm.

Evidence like this could provide an indication of dangers for existing species. Once it becomes clearer what happens to genetic diversity as a species approaches extinction, the information can be presented to those in charge of conservation policy, says Schuster. "You could then take these hardcore sequencing data to political decision-makers and say 'this absolutely has to stop'."

ILLUSTRATION BY DANIEL ALLISON, DAVID TIPLING/FLPA, PENN STATE UNIVERSITY

amid the otherwise grey population of Italian wolves. There's good evidence the gene responsible for black fur came from dogs, entering the wolf population after a dog-wolf liaison. "There is a whole group in Italy, including scientists, who want all black wolves killed because they are not pure," says Wayne.

But his analysis of the genomes of black-coloured wolves reveals no trace of recent dog ancestry, which means the hybrids from the dog-wolf pairing probably occurred hundreds or even thousands of years ago. So the black wolves are essentially Italian wolves and, Wayne says, culling them would be an "essentially racist" act.

Sequencing saves species

Dozens of other species are now benefiting from having their genomes sequenced. Many of these species have close relatives threatened with extinction. And as the cost of DNA sequencing continues to tumble, many more genomes will soon be available for scientists to study.

One project that could have a huge impact on conservation is Genome 10K, a bold initiative to sequence the genomes of 10,000 vertebrate species, thereby creating a 'genomic zoo'.

"I think it's going to be like a pebble in a pool, a large expansive effect," says Dr Oliver Ryder of the San Diego Zoo in California, one of the directors of Genome 10K. Launched in 2010, one of the project's key goals is to sequence as many threatened species as possible; over a quarter of the vertebrates currently identified by Genome 10K are on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species.

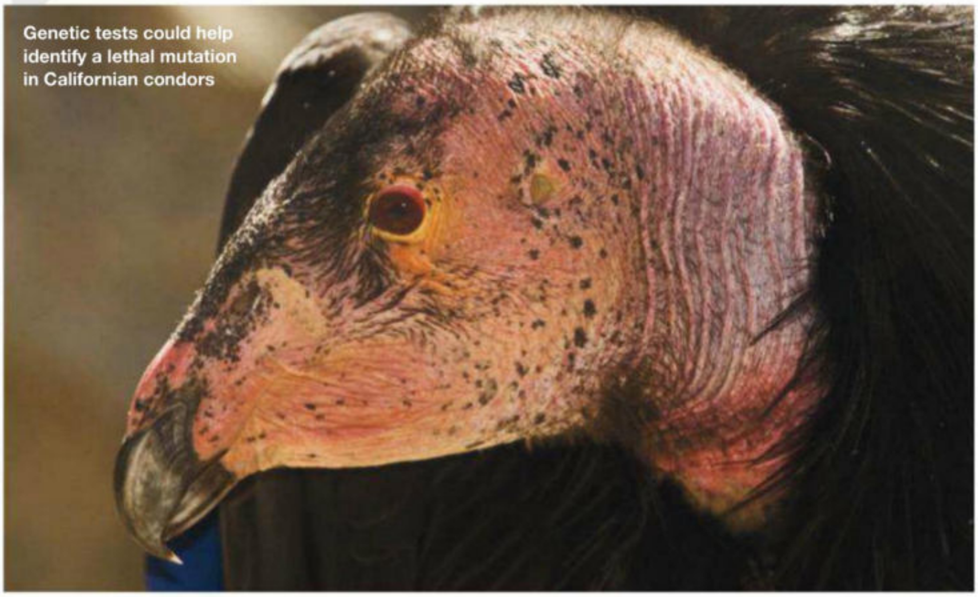
Not only will all these genomes improve the accuracy of conclusions that can be reached in the name of conservation, they also open up exciting new avenues that would have been unthinkable a decade ago. It's still early days, but plenty of projects are already attempting to go beyond junk DNA and identify regions of the genome associated with specific features, such as identifying harmful genetic mutations.

Conservation geneticists like Ryder hope genome sequencing could help save the Californian Condor, for instance. In 1987, with the species suffering from several threats (including habitat loss, hunting and poisoning), conservationists rounded up the last few wild individuals – just over a dozen – and brought them into captivity. Unfortunately, several condors turned out to have a genetic mutation that caused chondrodystrophy, a lethal condition in which the big bird's bones fail to develop properly.

DNA sequences can be used to pinpoint individuals with a valuable set of genes

Although the captive breeding and reintroduction effort has been successful, with more than 100 condors now returned to the wild, many carry the lethal mutation. Using the chicken genome (sequenced in 2004) as a guide, Ryder's team is aiming to pinpoint the mutation in the condor genome. This would then allow a simple genetic test to identify those birds carrying the mutation, thereby helping to manage the captive population more effectively.

Genome sequences can also be used to pinpoint individuals with a particularly valuable set of genes. In 1996, conservationists in Tasmania noticed a contagious cancer spreading through the island's iconic Tasmanian devils. Since then, 'devil facial tumour disease' has wiped out 90 per cent of the population in some places, and it's feared it could result in the total ▶



Genetic tests could help identify a lethal mutation in Californian condors

▶ extinction of the species within just five years.

One devil, called Cedric, seemed to have something the others didn't: immunity to the disease. Geneticists went all-out to sequence Cedric's genome in the hope it might reveal his secret. If they could work out what was so special about his genetic make-up, they could look for similar sets of genes in the remaining wild population and collect these resilient individuals to form part of a captive-bred population kept on the Australian mainland.

"We were hoping that our data would be considered useful for making the breeding decisions in this insurance population," explains Professor Stephan Schuster of Pennsylvania State University in the US, who helped sequence Cedric's genome in 2009. Although Cedric sadly succumbed to the cancer in 2010, his genome lives on as a string of letters in DNA databases, which could yet prove useful in preventing his species going extinct.

If conservation geneticists can get to grips with which bits of a genome are adapted to which environments, they might even be able to anticipate how a species will fare when confronted with threats such as climate change – and take appropriate action to help. For example, Fred Allendorf imagines a forest in which the trees don't have the genetic variation required to deal with warmer, drier conditions. "If we could move in pollen or genes from populations of that same species that have already been facing that [tougher] environment, then we can assist them in adaptation."

Conservation in action

A species' own genome isn't the only DNA sequence that could be valuable for conservation. Animals can host a characteristic set of microbes, so scientists can identify which ones are present by sampling these microorganisms and sequencing their DNA. A coral reef in good health will have a signature-like suite of microbes, for example, and a shift in this balance can indicate that something is wrong. Sampling microbes could therefore provide a quick feel for the health of an ecosystem, and understanding the mechanisms underlying their collapse could prevent it happening.

Sampling microbes could also help assess the fitness of particular

HELPING HYBRIDS

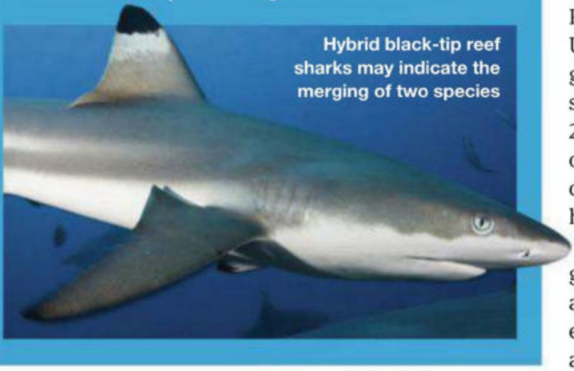
More and better genetic information sounds like it should be good for conservation, but it can reveal new problems that would otherwise have gone unnoticed. Take research on sharks off the Australian coast, for example. The Australian black-tip shark and the common black-tip shark are considered separate species, with clear differences in body length and genetic make-up. But their ranges overlap and despite sharks having internal fertilisation, which normally prevents different species from mating, geneticists have identified 57 hybrid sharks along a 2,000km-long stretch of coast from northern Queensland to New South Wales.

Better genetic information can reveal problems that were previously unnoticed

This discovery raises many questions. But in blurring what had been a clear distinction between two species, it also creates problems for people interested in the sharks' conservation. Is this hybridisation a natural phenomenon, allowing them to adapt to environmental change? Should the hybrids be protected? Should marine conservationists try to prevent interbreeding between the two species?

On the basis of the genetic data collected so far, it's impossible to say whether these sister species have been interbreeding for centuries, or whether it's a more recent phenomenon. "We hope that more screening will answer this question," says molecular biologist Dr Jessica Morgan of the University of Queensland, lead author of the study published in the journal *Conservation Genetics*.

It will also be important to work out how the genetic fitness of the hybrid offspring compares to that of their purebred parents. Hybrids are often unable to reproduce, but in this case it seems they can. More research will help predict whether the Australian and common black-tips are likely to merge into one or remain two distinct species, says Morgan. "It's too early to know what impact the hybrids are having on the species. A lot more information is needed before hybrid management is considered."



Hybrid black-tip reef sharks may indicate the merging of two species

PRESS ASSOCIATION, ILLUSTRATION BY DANIEL ALLISON, DAVID FLEETHAM, NATUREPL.COM

Researcher Alex Kreiss with Cedric, the Tasmanian devil whose genome was sequenced to battle cancer

individuals. Researchers have recently identified the suite of gut microbes contained in a giant panda's faeces – organisms that may be crucial for the digestion of the cellulose in bamboo. Wild and captive pandas have a very different balance of these microbes, perhaps suggesting that, compared with their wild counterparts, captive pandas aren't as efficient at handling all that cellulose.

Microbes might also help account for the mysterious collapse of honey bee colonies across the US. By sampling microbes associated with bees, pollen and honey, it's looking increasingly likely that viruses are responsible for the demise of American bees, hitching a lift into healthy colonies aboard grains of pollen. It's possible the honey bee genome, published in 2006, could be used to help identify queens resistant to viral infections.

Habitat remains vital

In principle, conservationists hoping to bring the short-haired bumblebee back to Britain in spring could also use the honey bee genome to further their work. But for such small projects, where funding is tight, cutting-edge genomic research is still relatively expensive and unlikely to be the top priority. For now, it is more important to ensure that suitable habitat is available for the bees to spread northwards across Kent, maybe even one day finding their way back to every part of their historic range.

There are, however, clear limitations on the usefulness of genome sequences. One concern is that genomics may be giving the people who make conservation policy decisions too much information. Take Robert Wayne's work on wolves, for instance, which indicates that the critically endangered red wolf may actually be little more than a recent descendant of a hybrid of grey wolves and coyotes. Although the finding raises serious doubts about the value of investing millions in red wolf conservation, Wayne says the US Fish and Wildlife Service aren't listening. "They really don't want more headaches, I don't think."

Fred Allendorf has had a similar experience with conservation managers while working with trout in the American Northwest. "Using new molecular markers we can now detect hybridisation where we couldn't before, and many of the [conservation] managers wish we couldn't detect hybridisation because it makes life a lot more complicated."

Even if traditional conservationists were more prepared to act on the insights from the genome, Allendorf explains that there's a rather more profound reason why DNA data will only ever be a part of the wider conservation picture, and that's the continued destruction of essential habitats. "No increased amount of genetic understanding is going to solve that problem." ■

***Dr Henry Nicholls is a science journalist and author of* The Way Of The Panda**

FIND OUT MORE

The short-haired bumblebee project
http://j.mp/SubTbee

BBC RADIO 4 92–95FM & 198LW

***The Living World* is on BBC Radio 4 on Sundays from 29 April**

worldmags.net

Q&A

Your questions answered

How do woodpeckers avoid brain injury? p78
Is cold water heavier than hot water? p79
What makes the holes in Swiss cheese? p80
Why do we have so many teeth? p82

How does granite form?

Granite is made of magma that solidifies more readily than the magma around it. This occurs because in most mixtures of molten minerals, there's a specific proportion that has a higher melting point than the others. This is called a eutectic mixture.

In the same way that fractional distillation changes the ratio of different mixed liquids, fractional crystallisation separates the lower melting point compounds and drives the magma towards its eutectic composition.

When the magma cools below its specific melting point, it solidifies into a huge lump, called a pluton. This works its way up to the surface through geological weak points and can be exposed on the surface when the softer, sedimentary rock above it wears away. **LV**

How do we learn to walk?

Much of our ability to walk upright appears to be hard-wired: simply holding infants upright and moving them across the floor is enough to make them take 'baby steps'.

New research shows that we inherited some of the necessary brain circuitry from other mammals, such as rats. What makes us different is that by the time we become toddlers, we're using this circuitry in much more sophisticated ways, allowing us to both walk upright and grasp things at the same time. **RM**

How do bats hear ultrasonically?

They emit rapid high-pitched clicks and measure how long the echoes take to come back. This means they can perceive distances and build a picture of the world around them.

Some species cruise around clicking quite slowly so as not to waste energy but speed up their clicking when homing in on prey or approaching a hazard. How they sort out the echoes depends on the species. Some use the Doppler shift to work out their speed relative to moving prey. Others emit sounds with a downward-swooping pitch, so the returning echo is lower in pitch the further away the object is.

Many bats can close their ears against the loud blast of their own click and then open them to receive the faint echo. Recent research has discovered that horseshoe bats can even change the shape of their ears. They do this in a tenth of a second, quicker than a human eye blink, to suit their echolocation to different sensing tasks. **SB**

GETTY X2, FRANZ CHRISTOPH ROBI/FLPA, THINKSTOCK

3.64 million

The average number of people passing through Tokyo's Shinjuku railway station each day

Send us your questions

questions@sciencefocus.com

Focus magazine Q&A,
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Bristol, BS1 3BN

What is the 'twin paradox'?

According to Einstein's theory of Special Relativity, time isn't the same for everyone. For example, if we observe a clock moving at a constant speed relative to us, it appears to mark time slower than a clock remaining with us. The time difference is only significant when you approach the speed of light.

Imagine a pair of twins, one of whom is an astronaut that travels to a distant star. The stay-at-home twin will see his brother age more slowly than him. You'd expect the space-faring twin to see the same happen to his Earth-bound counterpart since they're moving at the same speed relative to one another. But if the twins are re-united, Einstein said that the space-faring twin will have aged less than the one on Earth, which is odd given that they've both performed identical journeys relative to each other.

Einstein's prediction has been confirmed in experiments with atomic clocks, so what resolves this paradox? The answer lies in the fact that the twins don't undertake identical journeys. To get back to Earth, the travelling twin experiences a force in order to slow down and reverse direction. The stay-at-home twin doesn't, making their journeys fundamentally different. Not surprisingly, so are the relative travel times of the twins, thus one of them ages more. **RM**

ID YOU KNOW?

Saudi Arabia has more proven oil reserves than any other country. As of 2010, almost 20 per cent, or 264.1 billion barrels, of the world's oil reserves are found beneath the Kingdom.

Can photons be destroyed?

According to quantum theory, photons are the quanta (packets) of energy that carry every type of electromagnetic radiation – from radio waves through to visible light and X-rays to gamma radiation. As such, they can be both created – for example, by heating atoms or accelerating electrons – and destroyed, by striking absorbing materials like lead. **RM**

The **experts**

SUSAN BLACKMORE
Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*

DR ALASTAIR GUNN
Alastair is a radio astronomer at Jodrell Bank Centre for Astrophysics

ROBERT MATTHEWS
After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University

GARETH MITCHELL
Starting out as a broadcast engineer, Gareth now writes and presents *Click* on the BBC World Service

LUIS VILLAZON
Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach the Ground*

What's the fastest speed achieved by a non-petrol car?

When it comes to biofuels, engineering students from Boise State University in Idaho hold the record for the fastest vegetable-oil-powered car. In November 2011, they achieved 248.5km/h (155.331mph) in a Chevrolet S-10 pickup running on cottonseed and sunflower oil. The 5.9 litre-engined truck was fitted with a mechanical injection system, a separate tank for vegetable oil and a heating assembly to reduce the oil's viscosity, helping it run through the fuel system.

But of course the fastest non-petrol car is the Thrust SSC, the current land speed record holder, which achieved 1,228km/h in October 1997. It had turbofan engines powered by kerosene aviation fuel. **GM**

How do woodpeckers avoid brain injury?

The force endured by a woodpecker's head on each peck is equivalent to a deceleration force 1,000 times that of gravity. Humans would suffer brain damage with blows to the head that are tiny in comparison, and scientists have long wondered how the birds can cope with these forces.

Using new technology, including slow-motion photography, force sensors and CAT scans, researchers have identified three mechanisms that protect the woodpecker's brain. First, their hyoid bone loops around the whole skull and acts as a kind of safety belt. Second, the upper and lower halves of the beak are uneven and the birds also slightly turn their heads as they peck, which distributes the force. Third, plate-like bones with a spongy structure distribute the force around the skull, so their brains are well protected. **SB**

How can I avoid the 3pm slump?

Surprisingly, the answer may not be to have a chocolate biscuit as a pick-me-up. A 2011 study at Cambridge University found that certain neurons in the brain, called orexin cells, stimulate wakefulness and energy burning when exposed to amino acids. Glucose reduces the activity of orexin cells but amino acids prevent the cells from becoming blocked by glucose.

The 3pm slump happens when the carbohydrates you had for lunch have been metabolised into glucose, blocking your orexin cells and making you less alert. Carbohydrate also triggers insulin production, which increases the concentration of tryptophan in the bloodstream. Tryptophan is another amino acid, found in most meat, but this one is part of the seratonin-melatonin biochemistry and makes you feel sleepy. So a turkey sandwich for lunch will make you drowsy but an omelette will keep you alert. **LV**

HOLLY SALEWSKI, ALAMY, SUPERSTOCK, GETTY X2, SCIENCE PHOTO LIBRARY, THINKSTOCK, S&D&K MASLOWSKI/FLPA

Can one black hole swallow another?

STEVEN A COLLINS, BY EMAIL

Yes, they can. Astronomers have found that supermassive black holes were very common in the early Universe. It's thought that such huge black holes couldn't have formed by the slow accretion of matter and must therefore have involved the merging of smaller black holes. This can happen when entire galaxies collide, a surprisingly common occurrence. Most galaxies are thought to have a black hole in their core and during these galaxy collisions the black holes can spiral toward each other and eventually merge. Astronomers have already found galaxies containing two central black holes in a binary system, but have yet to catch a pair merging. With the next generation of gravitational wave detectors it may be possible to observe such events. AG

Why do some trees lose their leaves and not others?

RICHARD O'NEILL, GLASGOW

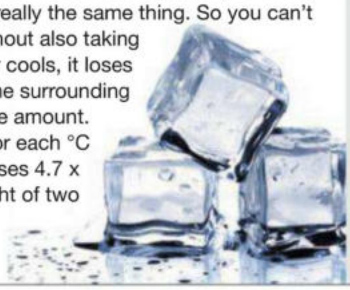
Shedding leaves is an adaptation for high winds. In winter the weather is much windier and large, broad-leaved trees present so much surface area that they're at serious risk of blowing down. At the same time, light levels are much lower, so the tree isn't missing out on much photosynthesising anyway. Evergreen trees usually have very narrow leaves to conserve moisture and aren't at so much risk from high winds. **LV**

Is cold water heavier than hot water?

MARTIN HUGHES, BY EMAIL

No. Cold water is denser than hot water (for temperatures above 4°C) because the individual molecules move more slowly and thus pack together more tightly. So a litre of water at 4°C weighs about 4.3 per cent more than a litre of water at just below boiling point. But that's because to fill a litre bottle with water at 4°C, you need to add more molecules of water than you do when the water is at 100°C. A greater number of molecules weighs more than a lesser number.

But if you take a sealed litre bottle of water at 100°C and let it cool to 4°C, without losing or gaining any molecules, you'd expect it to weigh the same. The really surprising thing, however, is that the mass actually drops. That's because Einstein's famous equation, $E = mc^2$, means that mass and energy are really the same thing. So you can't remove energy from a system without also taking some of its mass. When the water cools, it loses energy and therefore mass, and the surrounding air gains energy/mass by the same amount. The effect is very small though. For each °C that the litre of water cools, it loses 4.7×10^{-14}kg. That's about the weight of two human sperm cells. **LV**



DID YOU KNOW?

The original San Francisco-Oakland Bay Bridge opened in 1936 and required more concrete to build than the Empire State Building. The bridge cost $77 million to build, equivalent to $1.2 billion (£741 million) today but was left crippled by 1989's Loma Prieta earthquake.

QUICKFIRE

Why are some people such fussy eaters?

Fussiness is an adaptive advantage in young children because they're more vulnerable to poisons so it's safer to favour known foods. Adults are, generally speaking, more open to new tastes but some have a naturally more acute sense of taste, which can make them extra fussy; it depends on their past experiences with new tastes. Autistic spectrum disorders can also make people less receptive to unfamiliar foods. **LV**

Why do planets orbit in the same plane?

PATRICK STEVENS, BY EMAIL

Imagine a pizza chef making a base by tossing dough in the air. By spinning it, he makes the dough flatten out into a disc shape. The spinning cloud of gas and dust from which the Solar System formed flattened out in much the same way. The planets formed from the material of this spinning disc and so all ended up in approximately the same orbital plane. **AG**

THINGS YOU THOUGHT YOU KNEW

Can science explain how a bumblebee flies?

It's commonly said that science can't explain how a bumblebee flies. If you compare a bumblebee to a plane, then its flight does seem impossible due to its wingspan-to-weight ratio. But studies using high-speed cameras have shown that, unlike a plane's wing, which forces air down to push the wing up, the forward-back sweeping of a bumblebee's wings creates vortices in the air above their wings. The eyes of these mini-hurricanes have lower pressure than surrounding air, helping to keep the bee aloft.

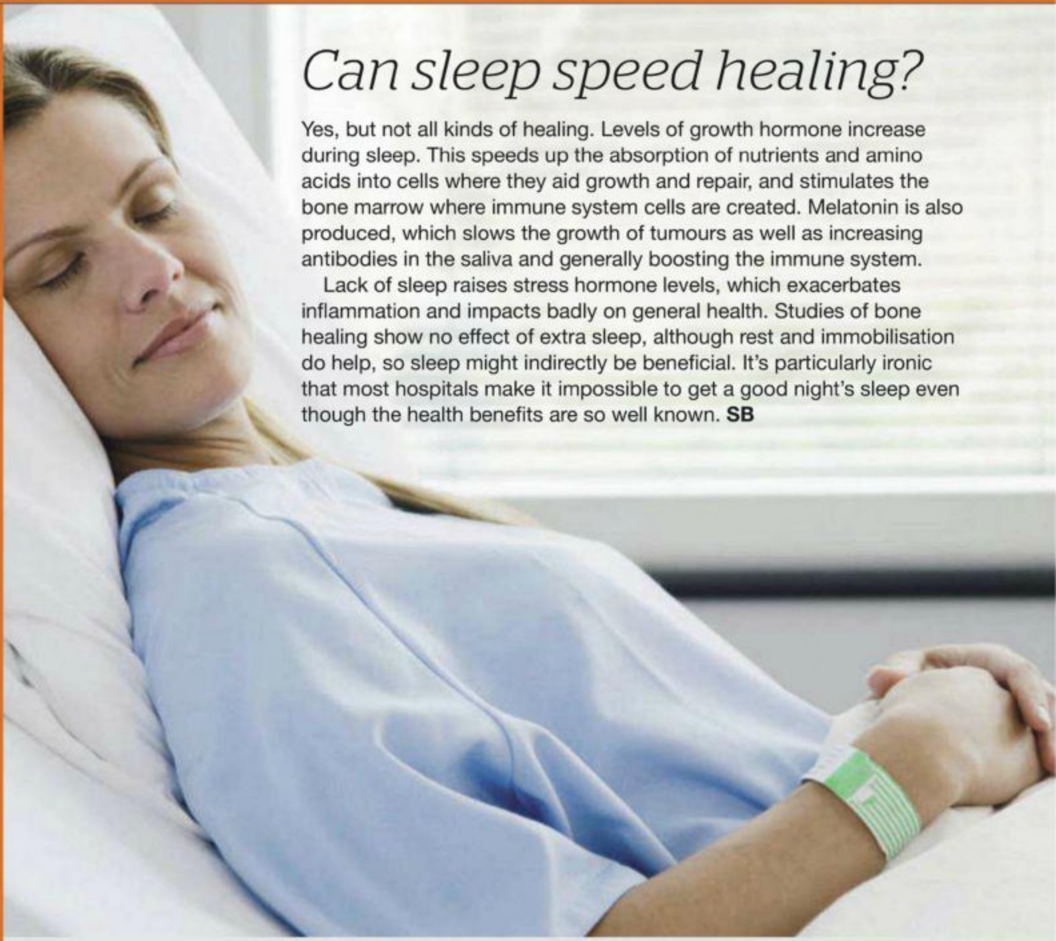
That said, bumblebees are inefficient flyers, as shown by a study in 2009. The researchers, based at Oxford University's Department of Zoology, trained bumblebees to commute from their hive to harvest pollen from cut flowers at one end of a wind tunnel. They used the wind tunnel to blow smoke past the flying bees and used high-speed cameras to take up to 2,000 images per second showing how the smoke flowed over the insects' wings.

The Oxford scientists concluded that bumblebees are the tanker trucks of the insect world, using brute force rather than aerodynamic efficiency to fly. Fuelled by energy-rich nectar, bumblebees flap their left and right wings independently around 200 times per second, a flying style that helps them hover and move around more easily while collecting nectar.

Studying insect flight is notoriously difficult, as insect wings are so intricate. But these studies clearly show that science can, and has, explained how a bumblebee flies.

Tiny wings, big body – how does the bumblebee do it? Science knows

ALAMY X2, SUPERSTOCK, THINKSTOCK, SCIENCE PHOTO LIBRARY, GETTY



Can sleep speed healing?

Yes, but not all kinds of healing. Levels of growth hormone increase during sleep. This speeds up the absorption of nutrients and amino acids into cells where they aid growth and repair, and stimulates the bone marrow where immune system cells are created. Melatonin is also produced, which slows the growth of tumours as well as increasing antibodies in the saliva and generally boosting the immune system.

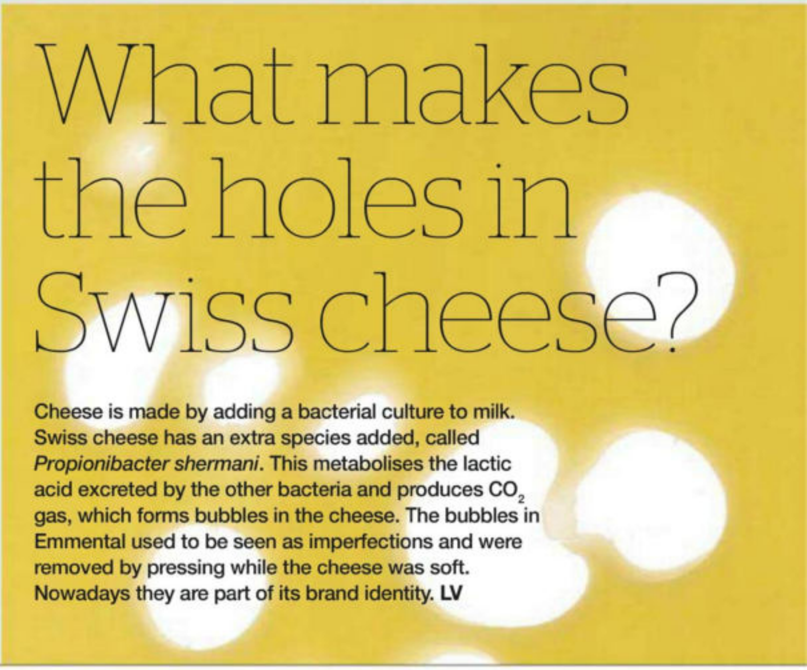
Lack of sleep raises stress hormone levels, which exacerbates inflammation and impacts badly on general health. Studies of bone healing show no effect of extra sleep, although rest and immobilisation do help, so sleep might indirectly be beneficial. It's particularly ironic that most hospitals make it impossible to get a good night's sleep even though the health benefits are so well known. **SB**

2:03:59

The fastest official time to complete a marathon, posted by Ethiopia's Haile Gebrselassie at the 2008 Berlin Marathon

DID YOU KNOW?

Mount Everest is growing! The geological processes that have led to the giant in the Himalayas becoming the world's highest mountain at 8,848m are still going strong and causing it to rise by 6.1cm each year.



What makes the holes in Swiss cheese?

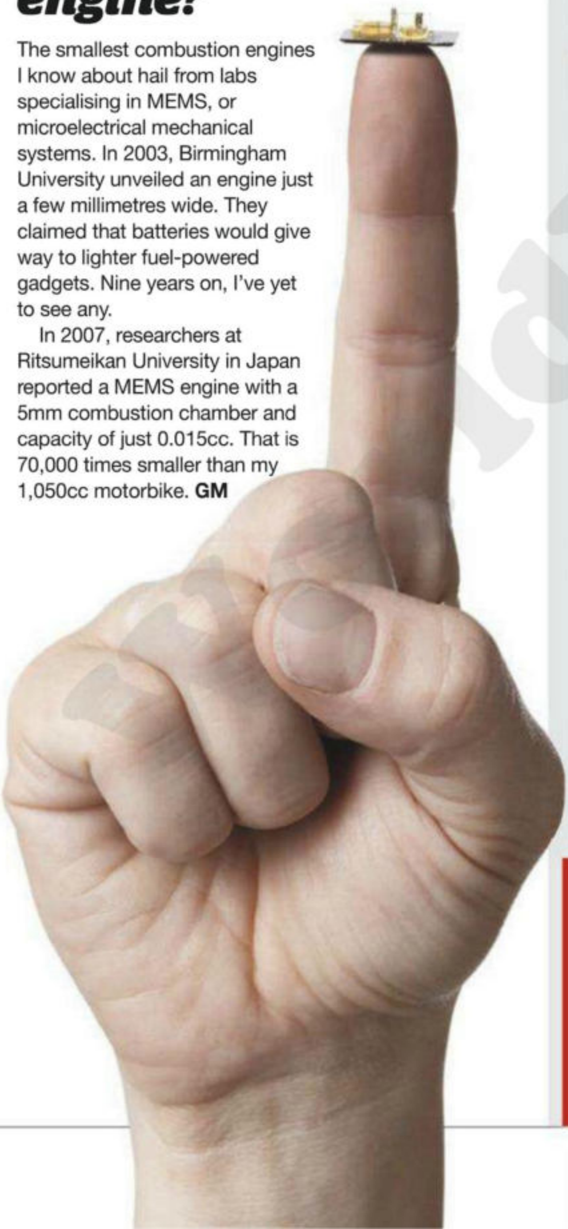
Cheese is made by adding a bacterial culture to milk. Swiss cheese has an extra species added, called *Propionibacter shermani*. This metabolises the lactic acid excreted by the other bacteria and produces CO_2 gas, which forms bubbles in the cheese. The bubbles in Emmental used to be seen as imperfections and were removed by pressing while the cheese was soft. Nowadays they are part of its brand identity. **LV**

Why do cups get hotter than their contents in microwaves?

Microwave ovens work by using electromagnetic waves to jostle the water molecules in food and liquids, thus heating them up. But sometimes it's the containers that end up getting most of the microwave energy. This can come as a nasty surprise when you find, say, the handle on your coffee mug is incredibly hot, while the coffee isn't.

According to microwaves expert Professor Ian Hunter of the University of Leeds, this is due to a concentration of microwave energy caused by resonance effects. These are familiar from playground swings: if pushed at just the right rate, a swing will go ever higher with little effort. If microwaves encounter features of just the right size and material, such as ceramic mug handles, the result can be resonance effects that concentrate the microwave energy in the handle, rather than the contents. **RM**

What is the world's smallest combustion engine?



The smallest combustion engines I know about hail from labs specialising in MEMS, or microelectrical mechanical systems. In 2003, Birmingham University unveiled an engine just a few millimetres wide. They claimed that batteries would give way to lighter fuel-powered gadgets. Nine years on, I've yet to see any.

In 2007, researchers at Ritsumeikan University in Japan reported a MEMS engine with a 5mm combustion chamber and capacity of just 0.015cc. That is 70,000 times smaller than my 1,050cc motorbike. **GM**

Do galaxies have life cycles?

ANDREW RICHARDSON, DURHAM

Galaxies are certainly 'born' and 'evolve', but they don't have a clearly defined 'life cycle' like stars do, for example. In the early Universe, 'proto-galaxies' were formed from tiny variations in the density of matter in space. As the proto-galaxies collapsed, the matter began to spin faster, thus flattening the proto-galaxies into thin discs. Within the discs, the density was high enough for stars to form and the first spiral galaxies were born.

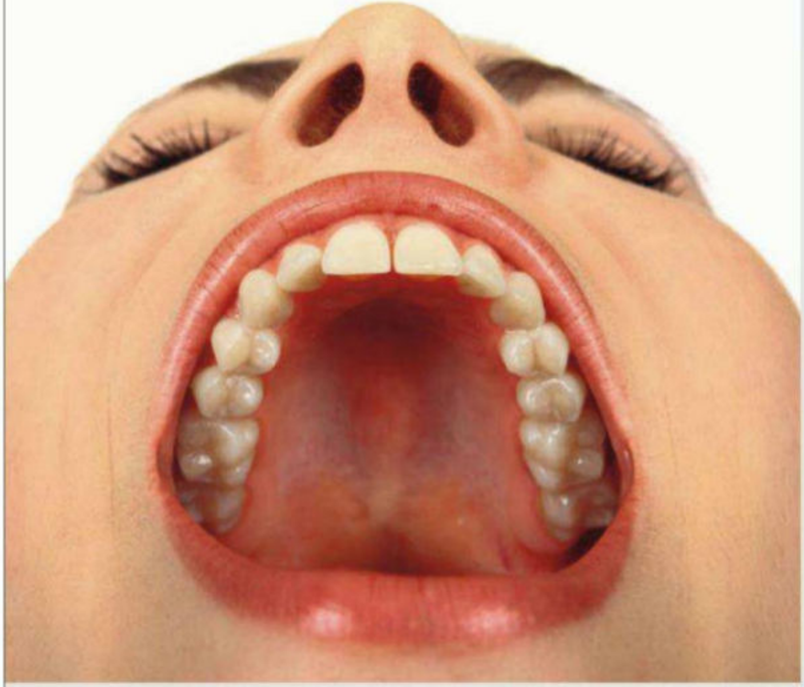
Since then, galaxies have evolved mainly due to the gravitational interactions between them. The merger of two spiral galaxies, for example, is so forceful that the stars in the incoming discs scatter randomly. What is left is a blob-like galaxy known as an elliptical. So, spiral galaxies evolve into elliptical galaxies, and irregular galaxies are those in the process of becoming one or the other. Some galaxies grow; some are swallowed up by their larger neighbours, but most regenerate their stellar populations and so never really 'die'. **AG**

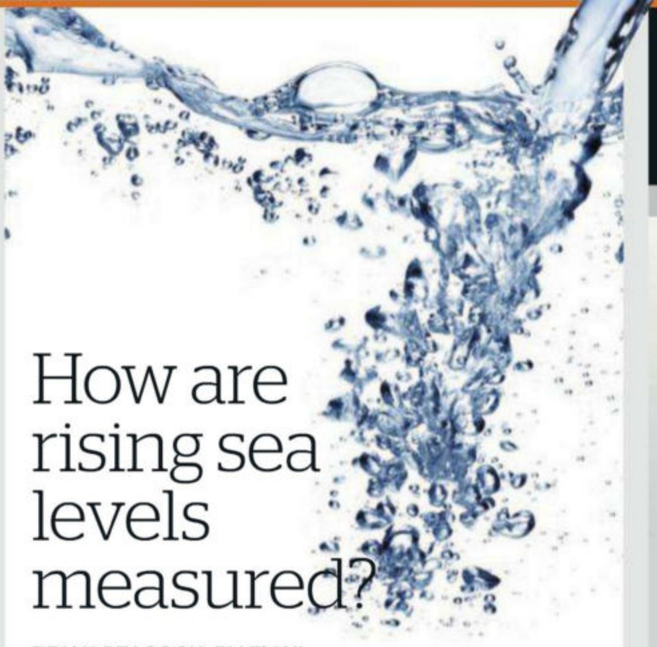
Why do colours induce emotions?

This is a tricky one because of the differing cultural traditions associated with colour. Experiments comparing British, Japanese, Chinese and others have found that people are made tense or relaxed by different colours. Other associations are independent of culture and children as young as three reliably connect colours with emotional facial expressions. But although we all associate colours with emotions, the underlying reasons remain mysterious. **SB**

Why do we have so many teeth?

Adult humans have 32 teeth, which isn't all that many – the Virginia opossum has 50 teeth and some dolphins have more than 250. The problem is that our jaws are too small for the teeth we have. A 2011 study at the University of Kent has suggested that this may be because we aren't hunter-gatherers any more. Agriculture and cooking have given us much softer food to eat and our jawbone has evolved to a shorter, wider shape more suited to that diet. Until we also evolve smaller teeth or fewer of them, we'll have to rely on the orthodontist to sort out the overcrowding. **LV**





How are rising sea levels measured?

BRIAN PEACOCK, BY EMAIL

It's a combination of measurements collected from tide gauges and satellite altimetry. Tide gauge data needs to be averaged over long periods to even out differences in sea level caused by tides and atmospheric pressure. Satellites can measure altitude to a precision of 20mm but they need to be constantly recalibrated to allow for orbital decay. Each system is used to refine the measurements of the other. **LV**

79.8m

The wingspan of an Airbus A380 passenger plane

Why are some clouds white and others grey?

PETE BREWER, IPAD APP

Clouds containing relatively large amounts of moisture absorb a lot of the light that enters them, making them look darker than their surroundings. On top of this is an effect known as chromatic induction, whereby we think things are darker than they really are if they're put against a light background. This makes slightly more moisture-laden clouds look ominously dark on a sunny day. **RM**

ALAMY X2, THINKSTOCK, ILLUSTRATION BY PAUL WOOTTON

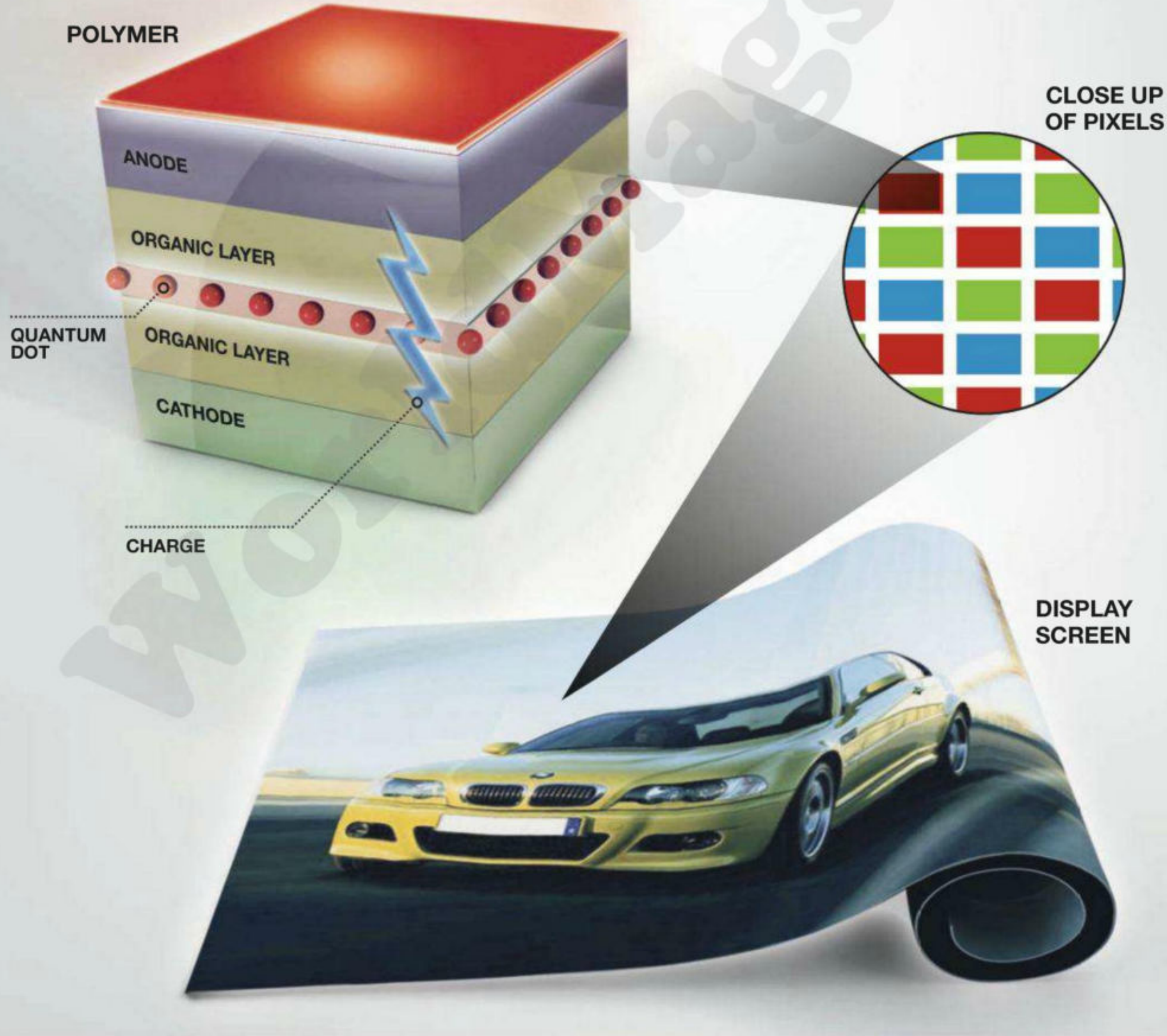
How it works: Quantum dot TV

Forget HD and 3D displays – the buzzword to look out for on future television sets is QD. The QD stands for 'quantum dot' (QD) and not only will a QDTV provide richer colour and consume less energy, it could be flexible enough to roll up and carry in your pocket.

Quantum dots are tiny manmade particles, between 2 and 10 nanometres (nm) across (about the size of 50 atoms) that emit bright light when excited by an electrical current or other light source. The colour of a quantum dot is completely dependent on its size. For example, a red dot is 10nm across, a green dot 5nm and a blue dot 2nm. Quantum dots have already shown potential in a number of different applications, from the manufacture of solar panels to the detection of cancer cells.

Now we are one step closer to seeing QDTVs hit the market place. The UK technology company Nanoco is hoping to make the first television sets containing its quantum dots commercially available by the end of 2012.

At first, the technology will be used to produce colour-enhancing backlights for existing LCD TVs. Here, layers of quantum dots are printed onto a translucent film, behind which an array of LEDs excite (switch on) the quantum dots through photoluminescence. However, it's their role in flexible televisions that could prove the most exciting application of quantum dots. In this case, the dots themselves will be turned on using an electrical charge. A base of conductive plastic will be layered up to construct the screen and quantum dots will be sandwiched between a transistor and topped off with a protective film. Once again the dots will be printed but this time in repeating patterns of red, green and blue dots to form a pixel array. The colour and brightness achieved on the screen by each pixel will depend on which dot is stimulated and to what extent. This technology is unlikely to see the light of day in consumer products until 2015.



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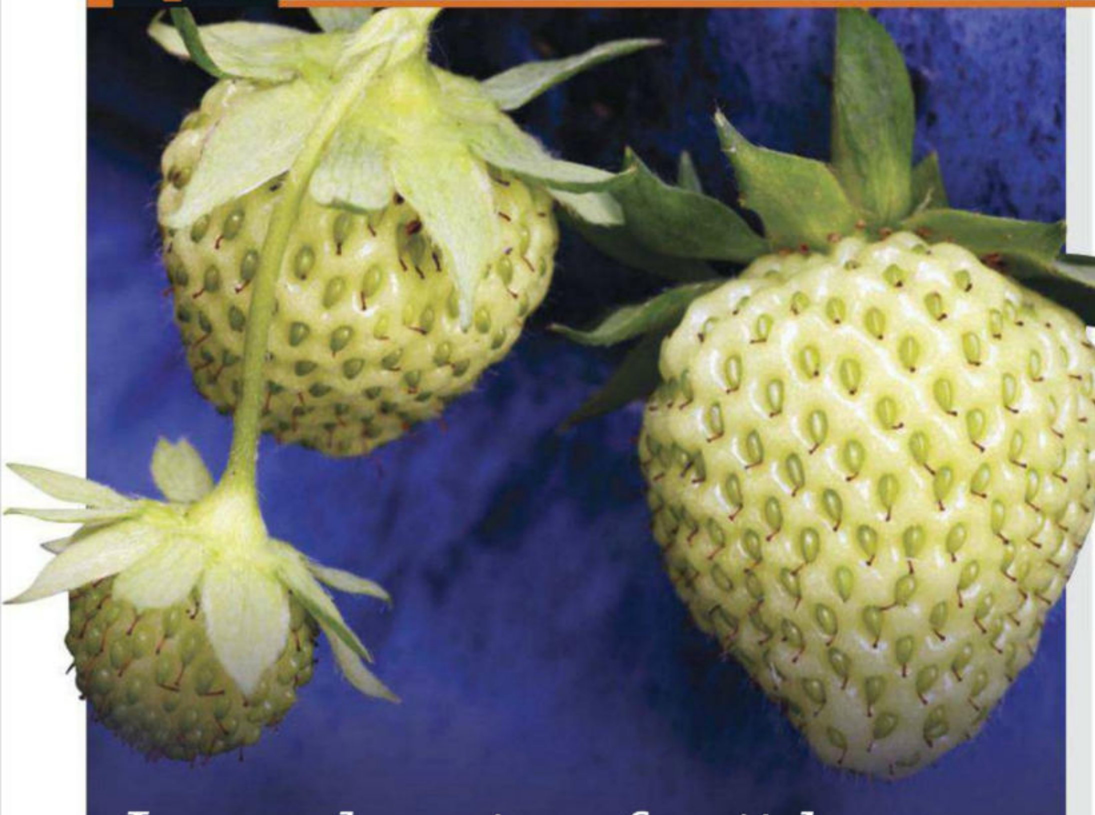
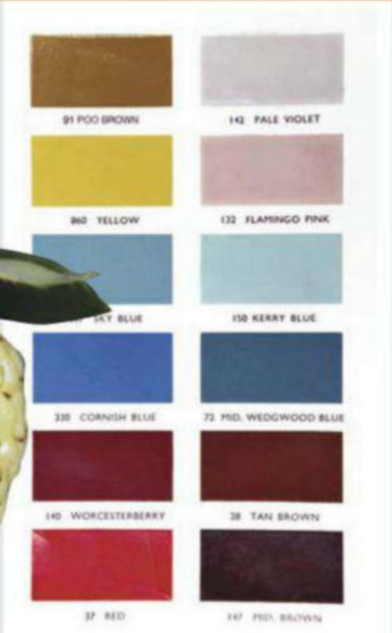


Is under-ripe fruit less nutritious than ripe?

A major change during ripening is that starch is converted into sugar, making most fruit taste sweeter when it's ripe even though the acidity may also increase. This happens because fruits evolved to be attractive to birds and insects that spread their seeds. Anthocyanin pigments and other antioxidants may increase with ripening but vitamin C levels rise in some fruits and fall in others. SB

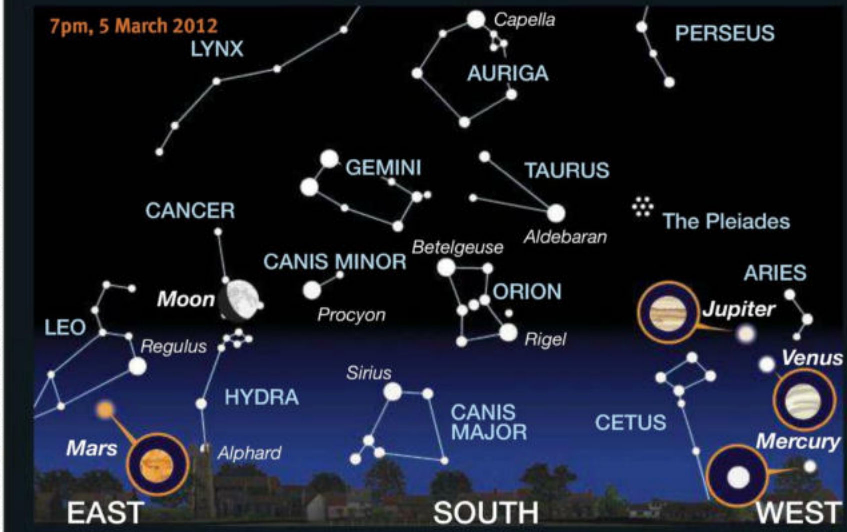


Why is poo brown?

MILLIE MCGIVEN, IPAD APP

It's the mixture of bile and bilirubin. Bile is secreted by the gall bladder into the small intestine to help fat digestion. Bilirubin is a breakdown product of the haemoglobin in old red blood cells that are dismantled in the spleen. Bile is a greenish yellow colour and bilirubin is yellow but the oxidising action of gut bacteria on bilirubin turns it into stercobilin, which is brown. **LV**

Skywatching with astronomy gurus Heather Couper and Nigel Henbest



A veritable parade of planets begins with Mercury in the west, just below Jupiter and Venus. Mars, rising in the east, is due south at midnight; Saturn follows at 10pm

What can I see in March?

- **3 March, southeast, all night**
Mars is at opposition – in line with the Sun and at its closest to the Earth. The Red Planet lords it up over the constellation of Leo all month.

- **5 March, west, 7pm**
Mercury sets an hour and 45 minutes after the Sun – just below Venus and Jupiter. It's putting on its best appearance of the year, and can be seen low in the west throughout the first half of March.

- **20 March, 5.14am**
It's spring! At the Spring Equinox, the Earth's northern hemisphere turns to face the Sun in its tilted orbit, so warmer days are on the way...

- **25 March, 1.00am**
...and brighter evenings. This morning, the clocks go forward by an hour (remember: 'spring forward, fall back').

Watch *The Sky At Night* on BBC One. Check radiotimes.com for details

BBC one

ALAMY X2, PRESS ASSOCIATION, THINKSTOCK, ILLUSTRATION BY PAUL WOOTTON

Is sense of humour quantifiable?

If you define a sense of humour as your likelihood of finding something funny, it's obviously possible to measure it, at least in a statistical sense. But simply finding everything funny doesn't mean you have a great sense of humour; it means you're an imbecile.

When we say someone has a great sense of humour, we generally mean they find the same things funny as we do and that's clearly a subjective measure. A 2007 study at the University of Granada in Spain found that there's no such thing as universal humour. We can measure how funny a group of people find a particular joke, but we can't place jokes in a universally agreed-upon spectrum of funniness. So you can't test your sense of humour simply by hearing 'reference' jokes and measuring your response. However, the fact that this study appeared in the *International Journal Of Humour Research* suggests there are academics willing to try. **LV**

Will computing move beyond silicon?

Silicon is an abundant element with valuable semiconducting properties. When doped with another material, silicon can flip from being an insulator to a conductor by simply applying a small charge. That switching property has ensured silicon's place at the heart of modern electronics. But various non-silicon technologies, like DNA computing, are causing a buzz.

Conventional electronics is based on 1s and 0s. But in DNA, molecules are represented by four letters: A, T, C and G. Within cells, enzymes read DNA much as a machine does binary bits. But in base 4, or quaternary, encoding each bit carries twice the information of binary, with potentially powerful processing possibilities. But DNA computing is unlikely to replace silicon in our PCs any time soon. One of the challenges to overcome is processing time. In June 2011, a Caltech team announced a molecular computer capable of calculating the square roots of small numbers. The trouble is, systems like these take around 10 hours to execute the equations. **GM**

QUICKFIRE

How will the new electricity pylons be installed?

PAUL STEVENS, BY EMAIL

In 2011, the government, National Grid and Royal Institute of British Architects held a competition to conceive the next generation of electricity pylons. The winner was a T-shaped design by the Danish firm Bystrup. With a single arm carrying the conductors, erection is expected to be much more straightforward than with existing truss designs. There are only four or five main parts compared to over a hundred in conventional towers. **GM**

Will we find new planets in our Solar System?

Astronomers discover thousands of new members of the Solar System every month. However, most of these are very small bodies like asteroids or comets. Larger objects (called 'dwarf planets') are occasionally found, although there are currently only five of these confirmed; Ceres, Pluto, Haumea, Makemake and Eris. But it's extremely unlikely that a large object, a fully-fledged 'planet', will have gone unnoticed in the Solar System. **AG**

DID YOU KNOW?

Holland boasts the world's tallest citizens. The average Dutch man stands 184cm (6ft) tall. It's handy seeing as 27 per cent of the country lies below sea level, making it the world's lowest nation.

3,600kg

The amount of krill a blue whale can eat in a day

NEXTMONTH

Why is water so essential to supporting life?
How do cells know when to stop dividing?
Why are repetitive noises so annoying?
How do solar sails generate thrust?

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For more answers to the most puzzling questions, see the Q&A archive

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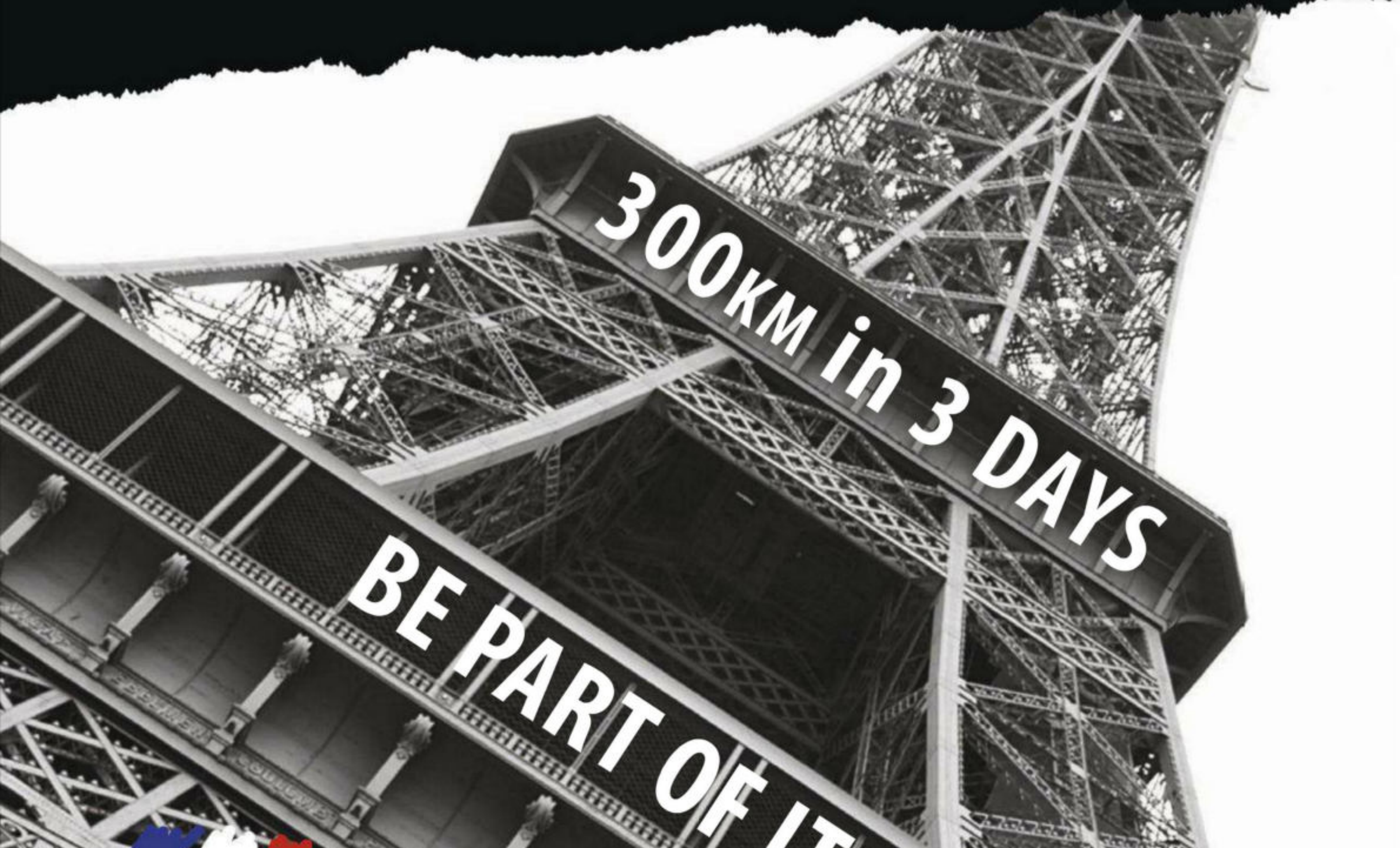

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The Guide

Everything for the clued-up consumer

Don't miss

The keyboard without keys 89
Timepieces for tech lovers 92
Make your gadgets damage-proof 101
Social media and TV collide 103

BENEATH THE BANDAGES

A new exhibition reminds us that mummies were people – and cats, says **Helen Pilcher**

Time was when an ancient Egyptian ordered a mummified moggie, he got what he expected – a preserved cat wrapped in bandages. But as their popularity for use as religious offerings grew, even hundreds of thousands of specially bred felines weren't enough to fulfil demand. Cat-shaped bundles full of sand or ashes were frequently peddled instead.

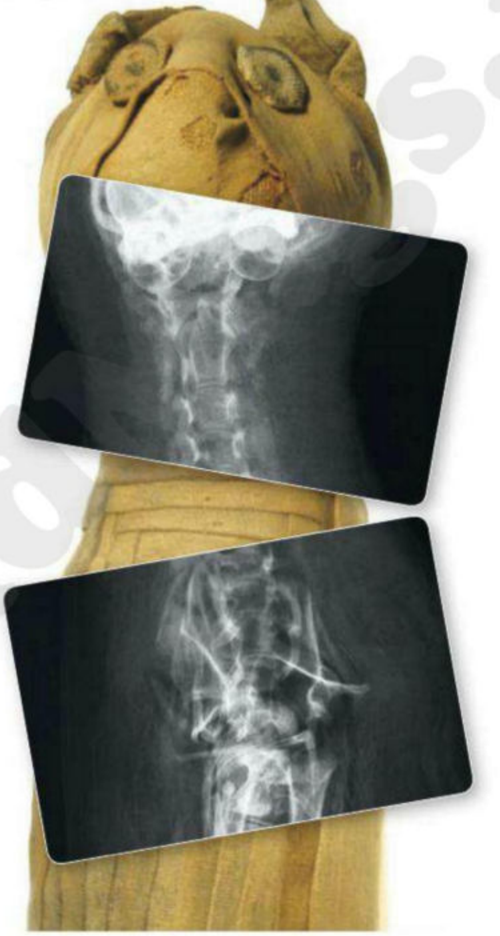
"People at the time may not have known what they were getting," says Maureen Barrie, Exhibitions Officer for the National Museum of Scotland and its new exhibition Fascinating Mummies. "But medical imaging techniques have made it possible for us to determine the true contents of these animal mummies."

Fascinating Mummies aims to show how modern technologies are adding detail and colour to what we already know about the people beneath the bandages from classical archaeology.

The exhibition features assorted mummies, coffins, jewellery, papyri and embalming equipment from the National Museum of Antiquities in Leiden, in the Netherlands, alongside items from the National Museum of Scotland's Egyptian collection.

One key exhibit is the mummy of Ankhhor and his three nested coffins. Traditional methods dated him to around 625BC, and hieroglyphic analyses told us that he served in the temple of the falcon-headed god of war Montu in Thebes (Luxor). His father was a priest and his mother a temple singer. Modern-day methods including X-rays and CT scans have revealed his age, height, unusually good teeth and the presence of various amulets and objects 'hidden' in his wrappings.

In the past, the destructive and often public unwrappings of mummies contributed to their being treated as curios rather than people, says Barrie. Fortunately for us, Ankkhor avoided this fate. "The insights offered by non-invasive, modern technologies are helping to give the mummies back their identity and their dignity," she says.



Ancient Egyptians believed that saying the names of the dead out loud made them live again. The first thing you'll encounter when you visit is a list of all the mummies' names. So don't be afraid to speak up!

Dr Helen Pilcher is a freelance science writer

Fascinating Mummies National Museum of Scotland, Edinburgh from 11 February to 27 May 2012. Visit www.nms.ac.uk for details. **Adults** £9, **concessions** £7.50, **child** £6 and **family** £26.

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The **Review** Squad

Helen Pilcher
Aside from being a fully qualified neuroscientist, Helen is also a science writer. She previews the exhibition that hopes to unravel the mystery of mummies (left).

Russell Deeks
As a self-confessed chronophile, Russ likes to figure out what makes the latest high-tech watches tick. He spends time with six of the best on p92.

Luis Villazon
Focus Q&A expert Luis is also an authority on home computer systems. He tests out network attached stroage systems for growing data demands on p94.

Spencer Kelly
The presenter of the BBC's *Click* programme turns his attention to how the expectations of today's kids will shape the way we interact with tomorrow's tech.

Bill Thompson
With over 25 years of working on and writing about the web, Bill is an oracle for the online world. He looks at how the web and TV are joining forces on p101.

RIJKSMUSEUM VAN OUDHEDEN X3

Speak French as it's really spoken

The audio magazine from France for learners of French brought to you by Languages Direct

Lively, relevant, entertaining

Published six times a year, *Bien-dire* not only helps you improve your fluency, it also helps you understand what it is to be French. The 52-page magazine is packed full of lively articles and in-depth interviews about France and French culture. There are regular features on a range of topics including travel, business, the arts, cinema, politics, sport, cuisine, popular culture, plus profiles on leading personalities and issues making the news.

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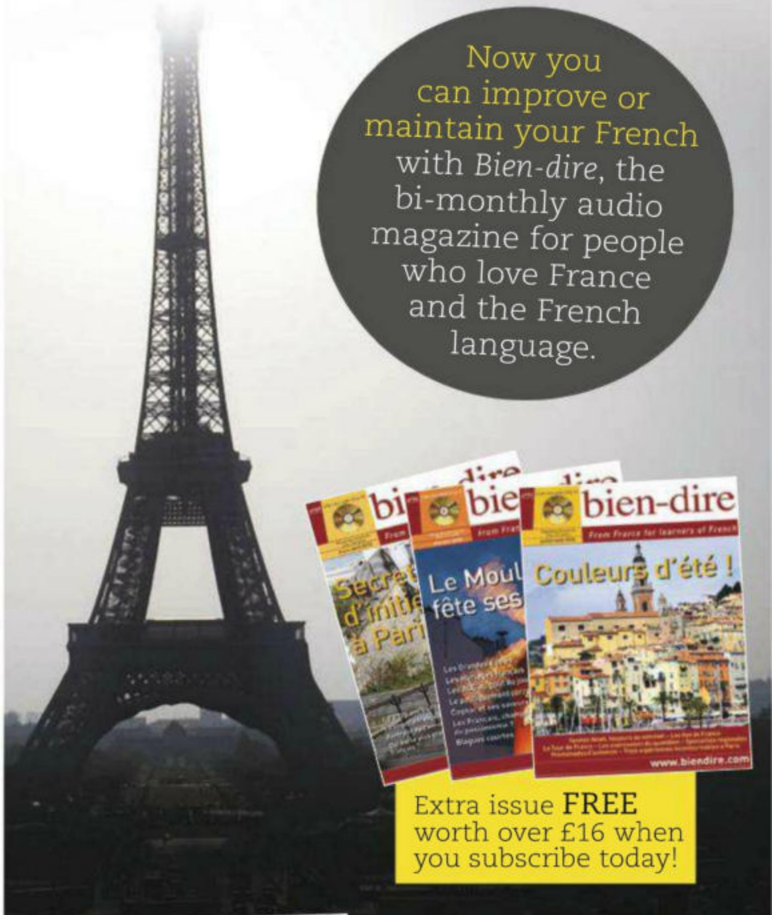
The accompanying audio CD is the perfect tool for improving listening comprehension and building confidence in speaking French. Put together by a team of professional narrators, each 60-minute CD provides well-paced readings of the key articles from the magazine, together with pronunciation and intonation exercises. The audio component of the subscription will enable you to improve significantly your ability to understand French as it's really spoken.



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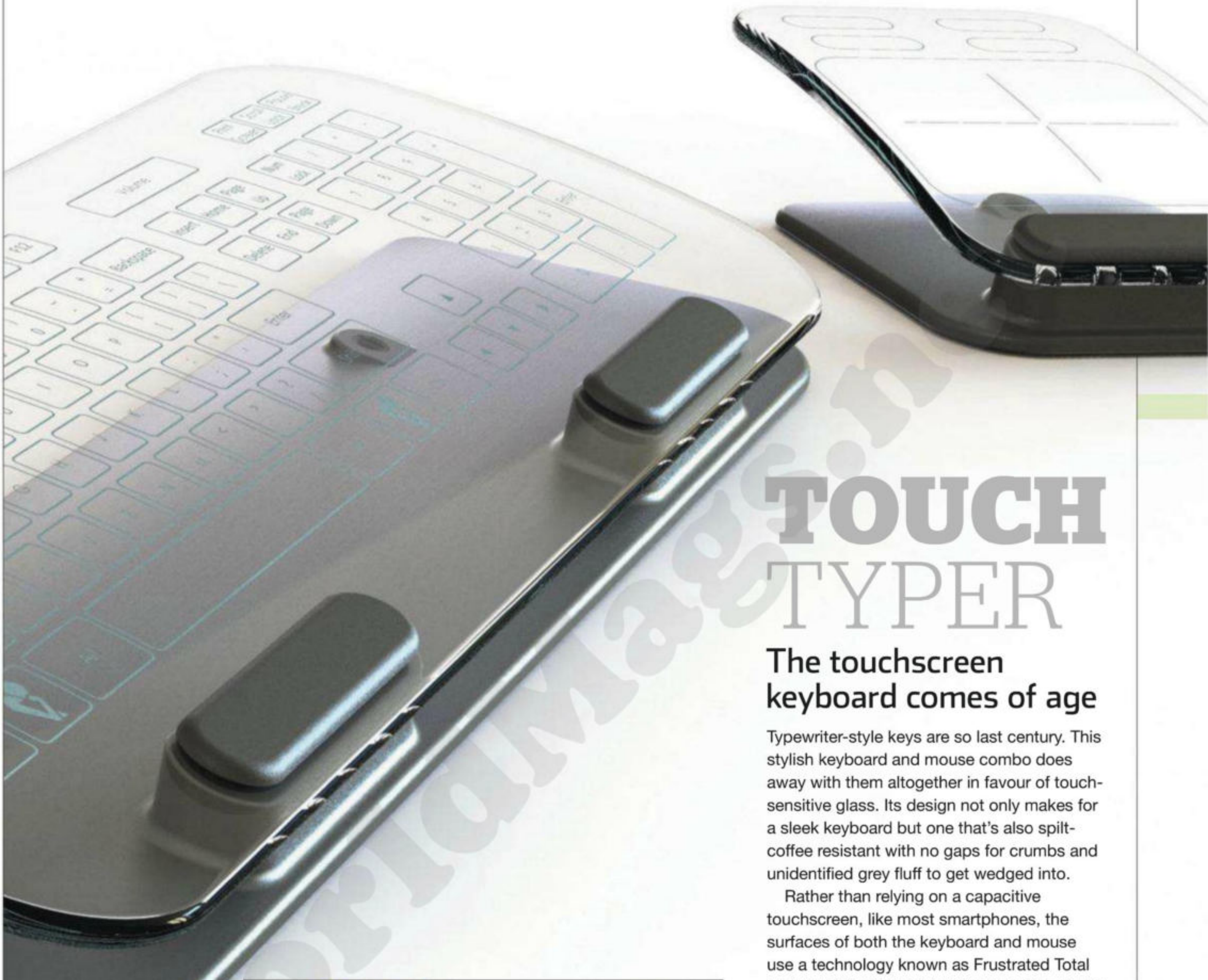

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TOUCH TYPER

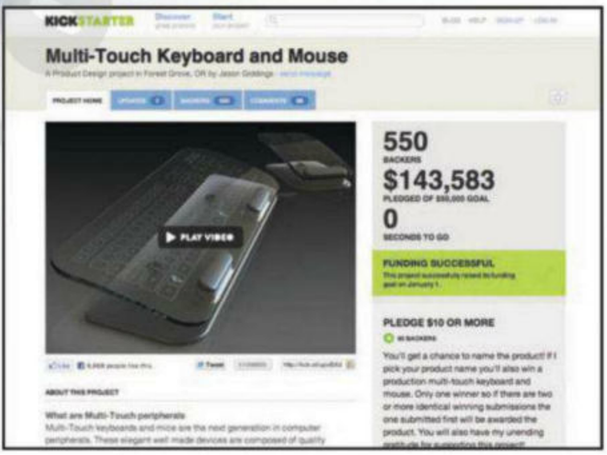
The touchscreen keyboard comes of age

Typewriter-style keys are so last century. This stylish keyboard and mouse combo does away with them altogether in favour of touch-sensitive glass. Its design not only makes for a sleek keyboard but one that's also spilt-coffee resistant with no gaps for crumbs and unidentified grey fluff to get wedged into.

Rather than relying on a capacitive touchscreen, like most smartphones, the surfaces of both the keyboard and mouse use a technology known as Frustrated Total Internal Reflection. This relies on LEDs hidden at the edges that shine beams of light into the glass. The beams are disturbed when you touch the surface, which allows a camera watching from below to see what key has been 'pressed'. In future, this system could be used to create interactive surfaces such as office desks (so you won't even need a keyboard) or shop windows.

Right now the keyboard and mouse are at prototype stage, but they've just received full funding from the crowd-sourced investment site Kickstarter.com. Early buyers can expect to receive theirs this year.

Multi-touch Keyboard and Mouse
Price: TBC
Info: j.mp/GlassKeyboard



Multi-Touch Keyboard and Mouse

A Product Design project in Forest Grove, OR by Jason Giddings

550
BACKERS

$143,583
PLEDGED OF

0
SECONDS TO GO

FUNDING SUCCESSFUL
This project successfully raised its funding goal on January 1.

PLEDGE $10 OR MORE

You'll get a chance to name the product! If I pick your product name you'll also win a production multi-touch keyboard and mouse. Only one winner so if there are two or more identical winning submissions the one submitted first will be awarded the product. You will also have my unending gratitude for supporting this project!

ABOUT THIS PROJECT

What are Multi-Touch peripherals

Multi-Touch keyboards and mice are the next generation in computer peripherals. These elegant well made devices are composed of quality

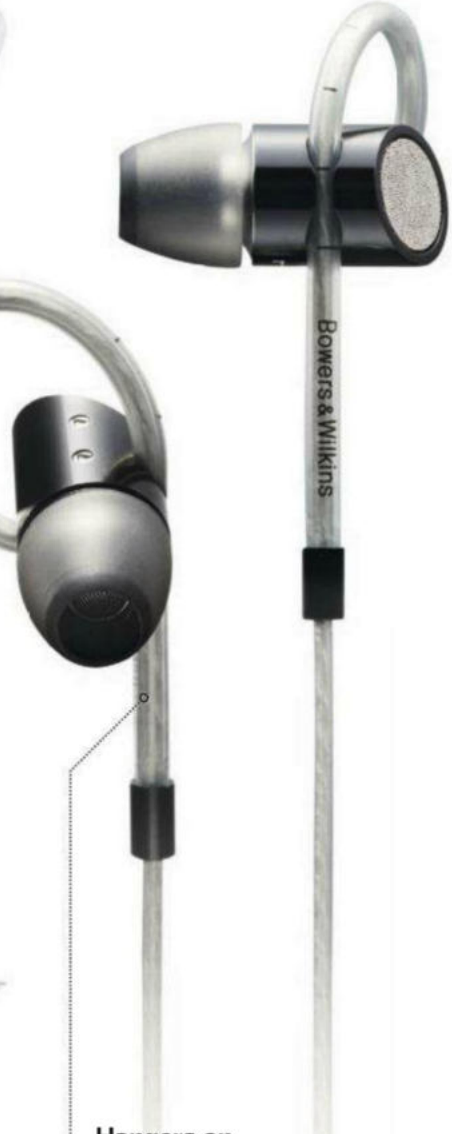
Funding to manufacture the keyboard and mouse has been secured through the crowd-sourcing website Kickstarter.com

Objects of desire

Mood lighting

Although we've seen plenty of MP3 players with unusual features, this is a first. Cowon's newest model offers a colour therapy mode to "heighten the emotional effect of your music". So, among others, you can choose an orange screen to pep yourself up or a purple one to relax. While we can't vouch for its effectiveness – people don't tend to stare at their MP3 players while they use them – its compatability is impressive. The iAudio10 will play dozens of file types that an iPod won't even go near.

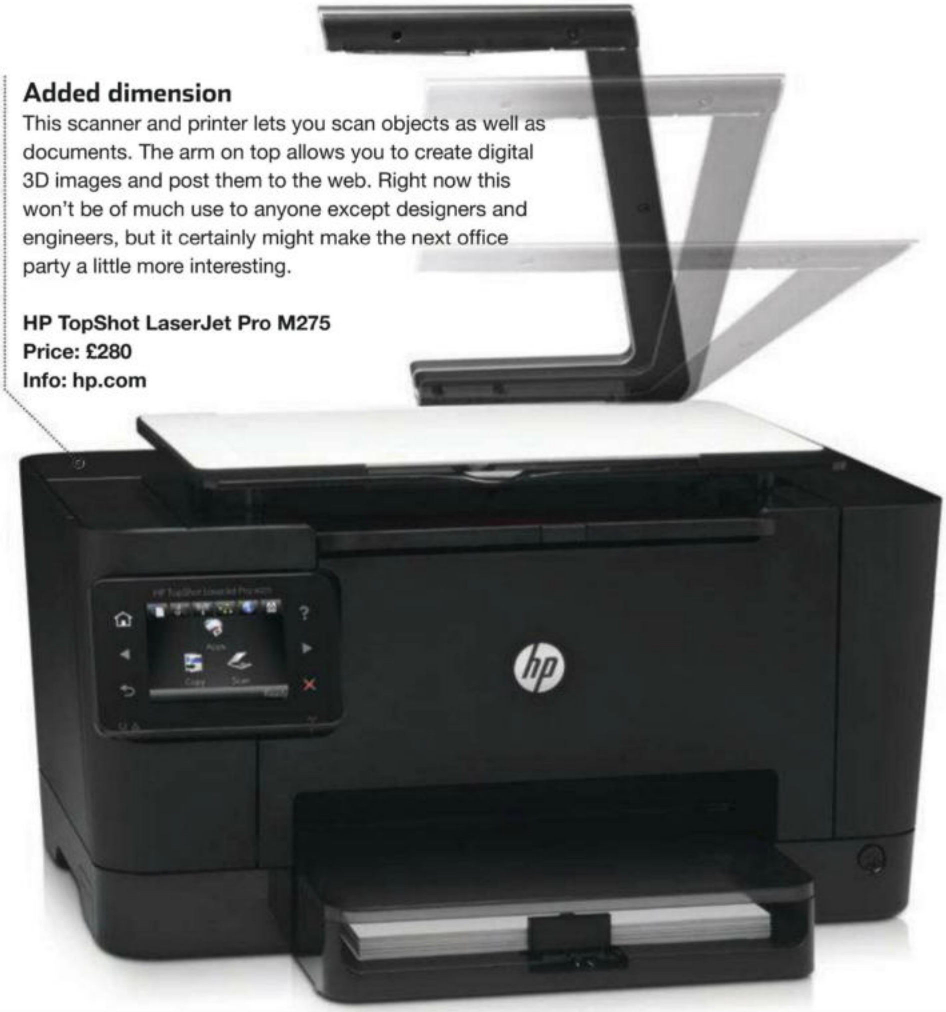
Cowon iAudio10
Price: £79 for 8GB model
Info: cowonglobal.com



Hangers on

This new design from Bowers & Wilkins lets you keep your earbuds in place without having to jam them into your ear canal. The small hoop fits snugly around the inside of your ear to hold the buds in place, so they're ideal for jogging or a trip to the gym.

Bowers & Wilkins C5
Price: £149.99
Info: bowers-wilkins.co.uk



Added dimension

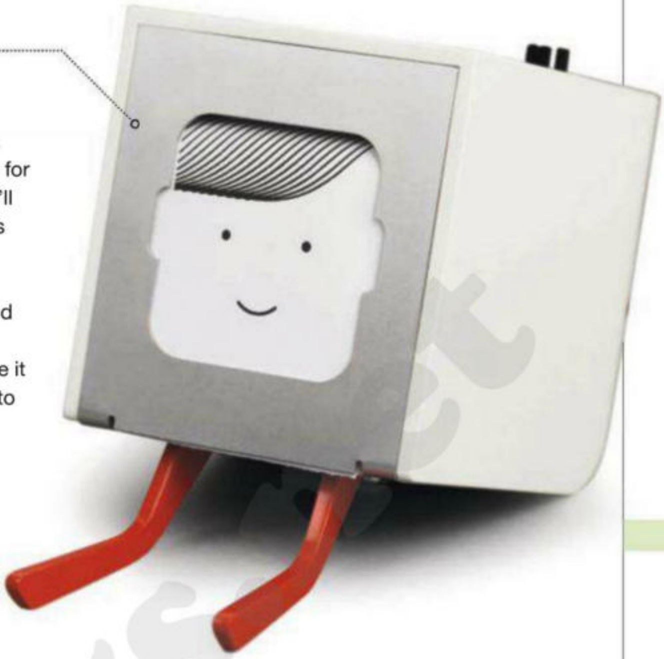
This scanner and printer lets you scan objects as well as documents. The arm on top allows you to create digital 3D images and post them to the web. Right now this won't be of much use to anyone except designers and engineers, but it certainly might make the next office party a little more interesting.

HP TopShot LaserJet Pro M275
Price: £280
Info: hp.com

A printer of note

If you pine for actual notes to stick in your diary or pin on a noticeboard rather than a beeping reminder, this pint-sized device is for you. It's connected to the 'cloud', where it'll take all the reminders and to-do list entries from your smartphone and print them out in a neat ticker tape-style strip. It'll even spit out highlights from social networks and news websites first thing in the morning. Best of all, it'll never run out of ink because it uses a thermal printer to heat your info onto specially coated paper.

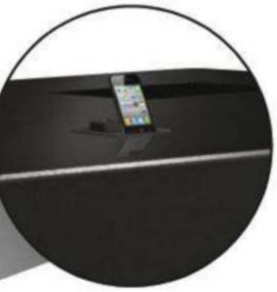
Berg Cloud Little Printer
Price: TBC
Info: bergcloud.com



Roll camera

Ever wanted to recreate one of those dramatic sweeping shots that are so impressive on the likes of *Frozen Planet*? The Camera Table Dolly will get you half way there. It's essentially a tripod (or rather a monopod) on wheels, so it needs a flat surface – a plank will do – to get a steady shot, but if you do, the effect is astounding. Now you just need to find something worthy of shooting.

Camera Table Dolly
Price: $90 (£57.50) plus approx $37 (£25) shipping
Info: photojojo.com



Big impact

This monstrosity is 2.5m long and 1.2m tall, making it roughly the size of a hippo, and that speck at the top is the iPod that's docked into it. The iNuke Boom pumps out 10,000 Watts of sound, making it as loud as it is large. Made by Behringer, a company that specialises in professional audio equipment for live performances, to promote the launch of its consumer range, the company is at pains to point out this isn't just a publicity stunt. You can buy this giant, if you can spare £19K.

Berhinger iNuke Boom
Price: $30,000 (£19,166) plus P&P
Info: www.behringer.com

worldMags.net

Six of the best

High-tech watches

Want to know what the best-dressed wrists will be wearing this spring? **Russell Deeks** has the answers

Best for... Cybergoths

Phosphor World Time Sport

This watch uses eink technology to display various configurations of local time, date and selected world times. You choose between them by tapping or swiping the two icons stamped into the watch's case, but a poorly translated manual means working out the correct combinations of gestures to achieve this isn't easy. The eink display is a nice touch and sets it apart from its more traditional counterparts.

Price: £125
Info: www.phosphorwatches.com

Best for... Seafarers

Nixon The Lodown T1

The Lodown uses a numerical and graphical display to show tide information for any of the 200 locations stored in its memory, for any date until 2020. Surfers are its primary target but fishermen and ocean-going types will find it useful. The tough strap uses a buckle but has an extra clip on the loop for added security. There's also a stopwatch, wave counter, alarm and a pleasing blue-green backlight.

Price: £130
Info: www.nixonnow.com

Best for... Outdoor adventurers

Nite NATO NA6-300T

This heavy-duty watch is built to take life's hard knocks – maker Nite says it's the ideal choice for "unarmed combat, orienteering and extreme survival training". It comes in a rugged, stainless-steel body and hands that glow so they can be easily read after dark. It's water-resistant to 300m and has a double-locking clasp, like the Nixon, to ensure it stays snugly on your wrist no matter how hectic things get.

Price: £329.95
Info: www.nitewatches.co.uk

Russell Deeks is a tech journalist and a self-confessed chronophile

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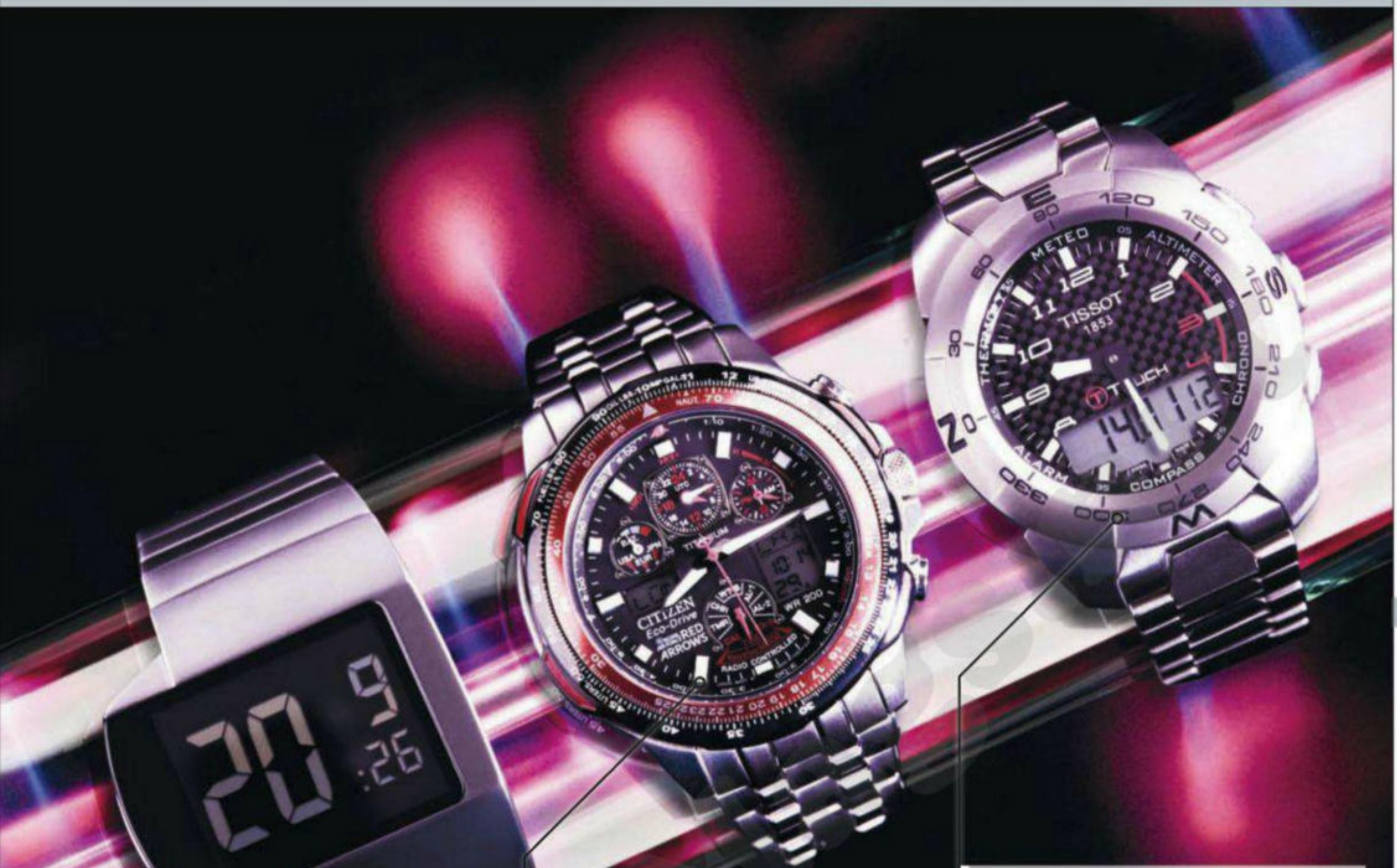

Best for... Fashionistas

Junghans Mega Futura

Like the Citizen Skyhawk, the Mega Futura has a radio link to the atomic clock, ensuring it keeps time precisely. The features list is limited to just a date/time function and a choice of 12- or 24-hour display, but it's by far the most striking watch here when it comes to looks. Its sleek, retro-futurist design is sure to attract admiring comments. It's quite chunky, but surprisingly light and comfortable to wear.

Price: £349.00
Info: www.junghanswatches.com

Best for... Aviators

Citizen Skyhawk A-T

The Skyhawk A-T uses Citizen's much-vaunted Eco-Drive technology (solar power to you and me) and is linked by radio control to the atomic clock for accurate timekeeping. It also boasts world time for 43 cities, two alarms, chronograph, calendar and countdown timer. All of which is enclosed in a titanium case that's water-resistant to 200m and carries the Red Arrows' seal of approval.

Price: £399
Info: www.citizenwatch.com

Best for... Alpha male types

Tissot T-Touch Expert Titanium

The T-Touch Expert is the most expensive watch here, but also has the most features. Pressing the 'T' button on the side activates its touchscreen display, allowing you to access thermometer, barometer, compass and altimeter functions by tapping different parts of the screen. Its rugged, masculine styling might not be for everyone – it feels quite heavy on the wrist for a start.

Price: £685
Info: www.tissot.ch

What to look for

Tech appeal
Just looking good isn't enough to warrant inclusion in the pages of *Focus*, a watch has to have the high-tech chops to match.

Ease of use
Being high-tech is no good if it means the watch is difficult to use – unless you have the patience to wade through a 68-page manual.

Bling factor
A watch is as much a piece of jewellery as it is a practical item. Will the timepiece cut the required dash when you strap it on?

Value for money
You want to invest wisely in a watch that has useful functions, not pay over the odds for a wrist-mounted white elephant.

Store, stream

Like a pull-out larder, Network Attached Storage is invisible most of the time but incredibly useful all of the time. **Luis Villazon** tests four units

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and share

Why you need Network Attached Storage

Your home is full of data. Media and documents are scattered around on different computers, tablets and smartphones. If you're savvy, you can sometimes share data between devices, but it's tricky to set up and only works when the devices are switched on.

Network Attached Storage (NAS) solves that problem by keeping your data in one place that's easy to access from all your devices. It's essentially a hard drive that stores everything you need at the centre of your network. It uses much less electricity leaving your NAS switched on than to keep all your computers on standby, and you can access everything from home or from anywhere with an internet connection. Think of NAS as the glue that could link all of your gadgets together into a proper network.

What you'll need

If you have broadband at home, you already have everything you need. Your Internet Service Provider (ISP) will have supplied a router that has both wired and wireless network connections. The NAS connects to the router with an Ethernet cable and can share data through the wireless connection in the router to everything else.

NAS devices need some simple configuration when they're first plugged in, so you'll need a Mac or Windows PC with an optical drive to run the installation software. Some NAS units are sold without the hard drive, so you'll have to buy one separately, but once you have it's as simple as plugging it into an empty dock.

How easy is it to set up?

For some of the devices tested here, it's not complicated in the slightest – the software wizard configures everything for you automatically. The more advanced ones have extra features that might take a little longer to figure out, but all of that is optional. You can be up and running with basic file sharing in 15 minutes with minimal hassle. If you can install a computer game, you can install a NAS device. ▶

What we tested

Setting up
How much network know-how do you need to install and configure the device? Does it work on a Mac and a Windows PC?

Controlling access
Can you securely get to your files through the internet? Is it easy to set groups and permissions for individual folders?

Ease of use
Can you quickly access files and folders from your home PC? What about from a tablet or smartphone?

Advanced features
What can it do besides store files and back up your data? Can you stream music and video? What about printer sharing?

worldmags.net

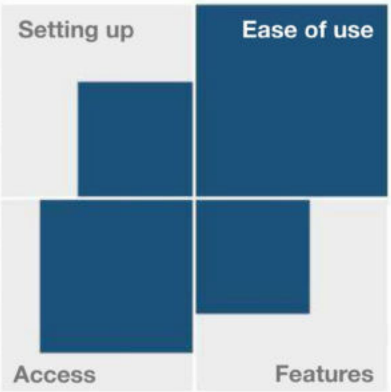
WD My Book Live 1TB

£99 www.wdc.com

+ This single-drive unit is a breeze to set up as it automatically detects your network settings and configures itself sensibly. It adds software called Quick View in the Windows system tray or Mac menu bar that tells you the drive's status – it also works well with Apple's own Time Machine backup system. Using its built-in 800MHz CPU and clever network optimisation, the My Book Live manages data transfer speeds that, under ideal conditions, are faster than a USB 2.0 external disk drive. There are also iPhone and Android apps to access the drive's contents remotely over the internet – with a security system that restricts access to just the devices you choose.

− Once it's set up, drive configuration happens through a special web page served by the My Book Live itself. This isn't very well designed, with a confusing frame-within-a-frame layout on some screens. The set-up page also seemed to hang quite often, particularly when accessed from a Mac. Recovery requires you to turn the My Book Live off and on again, which isn't good for the drives. The remote file-viewing app will tell you if the My Book Live is switched off but the photo-viewing app just shows an empty folder.

Drive bays: 1; Connectors: 1 x Ethernet; Hard drive storage: 1TB



> A very simple device to use and excellent value makes this an ideal NAS for beginners looking for basic network disk sharing

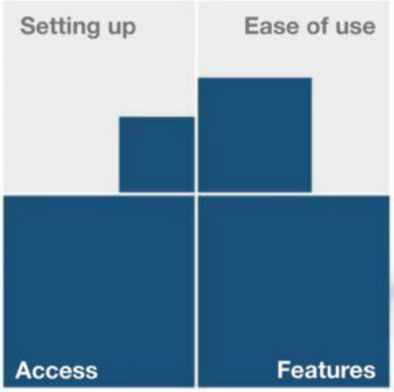
Synology DiskStation DS212j

£160 www.synology.com

+ The DiskStation feels solidly constructed, with room for two hard disks and a built-in alarm that beeps if the cooling fan fails. You can use the DiskStation as plain shared storage if you want, or for backup; it's compatible with Apple's Time Machine system and has its own backup software for Windows users. But you can also host your website, stream music, share a printer and automatically upload the photos you store on it to Facebook. There are five different iPhone and Android apps that let you send and receive music, photos and files, as well as remotely manage the DiskStation settings.

− You need to provide your own hard disks. It has several features aimed at network administrators that you'll probably never use: things like centralised access of server logs and backing up one DiskStation to another. The set-up process also assumes some technical knowledge. The "Create a Synology Hybrid RAID (SHR) volume" checkbox is ticked by default, leaving you to delve through the PDF manual to learn that this provides data redundancy at the expense of some storage capacity. Not necessarily the best option for home users.

Drive bays: up to 2; Connectors: 2 x USB, 1 x Ethernet; Hard drive storage: none supplied



> Sophisticated with great expansion potential. Requires the most technical expertise to set up of those on test

WWW.STUDIO4PHOTO.CO.UK

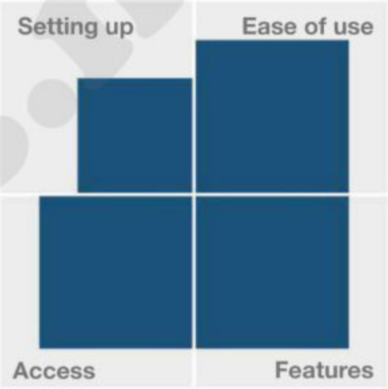
D-Link Sharecenter Shadow DNS-325 £100 www.dlink.co.uk

“Almost as advanced as the Synology and easier to manage. Needs a Windows PC to configure it”

+ The Sharecenter Shadow has a simple case design that allows you to open it and install up to two hard disks without a screwdriver. As part of the set-up process, you can create a domain name that allows you to access the Sharecenter from elsewhere on the internet. The Sharecenter can also send status information and alert messages to you via email. By choosing which applications you install on the Sharecenter during set-up, you can share a printer, stream music to a PlayStation 3 or XBox 360, access your files over the internet through a web browser and host photo galleries or a blog.

– Like the Synology, you must supply the disks. The set-up utility is Windows only and threw up some cryptic error messages during disk formatting in this test. Even when it works, the tone of the set-up wizard is quite techie and expects you to be familiar with DNS servers and different RAID configurations. If you don't know what these acronyms mean, you might find this a little daunting. The drives themselves are only loosely docked within the Sharecenter and might work themselves loose if you regularly move the drive around.

Drive bays: up to 2; Connectors: 1 x USB, 1 x Ethernet; Hard drive storage: none supplied



Seagate GoFlex Home 3TB

£199 www.seagate.com

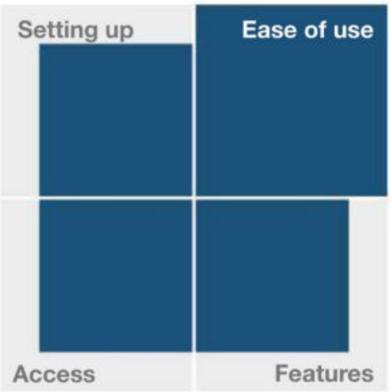
FOCUS BEST BUY

“Lots of features and simple configuration. A fantastic all-rounder, marred only by a few minor software glitches”

+ The GoFlex Home comprises a drive unit that sits in a docking cradle. This lets you easily move the drive between your home and office, for example, or store it somewhere safe when you go on holiday. If you want to increase your storage later, you can either replace the disk unit with a larger one or connect another external disk drive to the USB port on the docking cradle. Set-up works well on a Mac or PC and lets you register a unique name so you can access your GoFlex over the web via the Seagate Share service. You can also specify multiple email addresses that should receive alert messages. The GoFlex works with Apple's Time Machine but it also includes its own Memeo software for Windows backup. You can stream photos, video and music to a PlayStation 3 or XBox as well as your computer and you can access the folders from anywhere that has an internet connection using the iPhone and Android apps.

– We encountered some strange errors in the GoFlex Home Agent that's used to view your files from your computer. It's not anything you could describe as a serious problem, though, because you can easily access the files from Windows Explorer or the Mac Finder.

Drive bays: 1; Connectors: 1 x USB, 1 x Ethernet; Hard drive storage: 3TB



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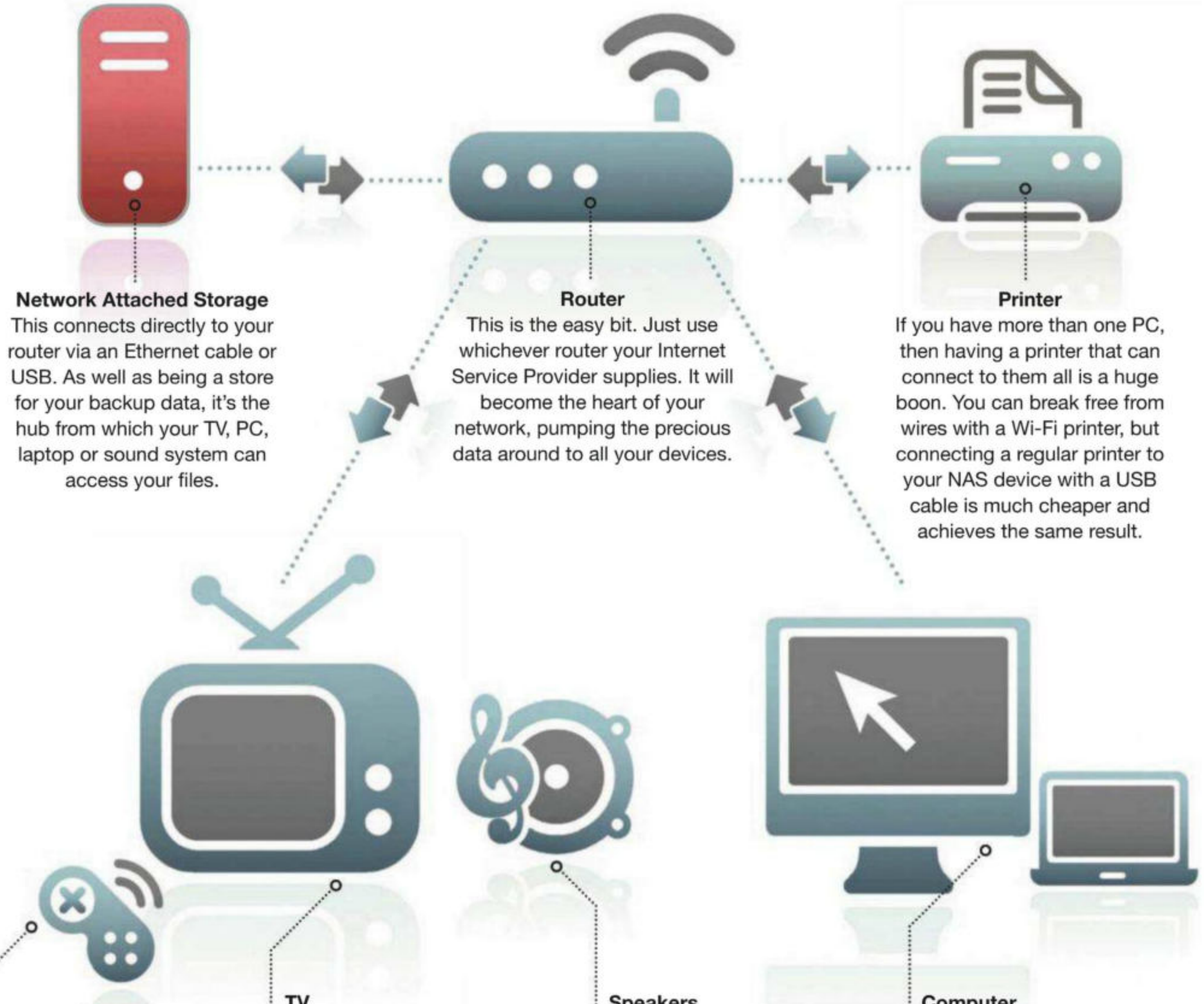
How to build a smart home around your NAS

Living in a home where all your tech is seamlessly connected and sending data back and forth isn't some futuristic fantasy. Here's how to make it a reality



Network Attached Storage
This connects directly to your router via an Ethernet cable or USB. As well as being a store for your backup data, it's the hub from which your TV, PC, laptop or sound system can access your files.

Router
This is the easy bit. Just use whichever router your Internet Service Provider supplies. It will become the heart of your network, pumping the precious data around to all your devices.

Printer
If you have more than one PC, then having a printer that can connect to them all is a huge boon. You can break free from wires with a Wi-Fi printer, but connecting a regular printer to your NAS device with a USB cable is much cheaper and achieves the same result.

Console
Both the latest Xbox 360 and PlayStation 3 support Wi-Fi connectivity and can be used to stream music and video files from your computer or NAS device to your TV.

TV
High-end TVs have built-in wireless connections to link to your router and are easy to set up. Once connected, you'll be able to enjoy iPlayer on your TV and also stream music and video files from your NAS or PC.

Speakers
Liberate your music from your PC with some wireless speakers. Systems vary, but they tend to have a 'bridge' device that's plugged directly in to your router and links your speakers to all your gadgets.

Computer
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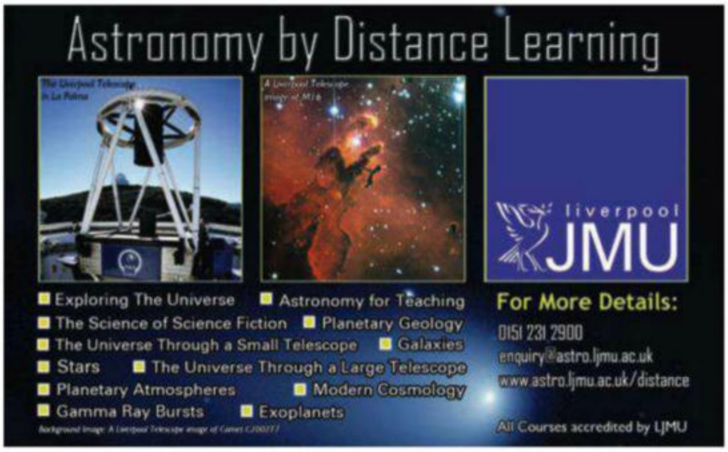
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The Liverpool Telescope in La Palma

A Liverpool Telescope image of M16

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How I Improved My Memory In One Evening

The Amazing Experience of Robert Heap

"Of *course* I place you! You're Bob Jones of Birmingham."

"If I remember correctly — and I *do* remember correctly — John Earnshaw, the supermarket man, introduced me to you at the dinner of the Bowls Club three years ago in October."

The assurance of this speaker — in the crowded corridor of the Hotel Piccadilly compelled me to look at him.

"He is Dr. Bruno Furst, the most famous memory expert in the world," said my friend Bob Clark.

As we went into the banquet room the toast-master was introducing a long line of guests to Dr. Furst. I got in line, and when it came my turn, Dr. Furst asked, "What are your initials Mr. Heap, your occupation and telephone number?" Why he asked this, I learned later, when he picked out from the crowd the sixty people he had met two hours before and called each by name without a mistake.

* * * * *

When I met Dr. Furst he rather bowled me over by saying: "There is nothing miraculous about my remembering anything I want to remember. *You can do this as easily as I do.*"

"That is alright for you, Dr. Furst," I interrupted, "you have given years to it. But how about me?"

"Mr. Heap," he replied, "I can teach you the secret of a good memory in one evening. I will prove it to you."

He didn't have to. His Course did; I got it the next day. Dr Bruno Furst's Course is fantastic!

I can rely on my memory now. I can recall the name of anyone I have met before — and I keep getting better. What's more, my concentration has improved.

My advice to you is don't wait another minute. Send for full details of Dr. Furst's amazing Course, available free on request (see the coupon below). You will be astounded to learn what a wonderful memory you could have. Your dividends in both business and social advancement could be enormous.

Robert Heap

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Spencer Kelly

The next generation

Week by week, my 20-month-old boy is learning more, making him more of a person and less of a noisy, fleshy food tube. He laughs, he plays and he can say "door" and "clock". But before he could do any of that, he could sit on my lap in my office and move the mouse and bash the keyboard of my PC. But the thing that fascinates him most is my smartphone. It has no buttons to press; it's just a black rectangle that does amazing things when you tap or swipe it.

My son is a touchscreen native. He's growing up in a world where computers are starting to understand us on our own terms: we point, they react. And now an Israeli tech company, XTR3D, has gone one step further and developed motion-control software for smartphones that would allow you to control your device with gestures – much like Kinect. This might seem like a strange idea, but if it's successful it won't be long before the software makes its way into TV set-top boxes, so you change channels with just a wave of your hand. The most exciting thing is that, being software, it could be used to upgrade almost any device with a camera to interpret gestures and movements.

Today's kids are growing up with touchscreen technology

But for now, the world's not quite ready. I don't have a touchscreen TV, not that it stops Spencer Jr covering ours with sticky fingerprints. And many of our paper magazines have been ripped and screwed because they don't light up and move at his touch.

Hopefully, as he grows up, technology can keep up with him and create new gadgets that can meet the expectations of a new generation of touchscreen natives.

Spencer Kelly is the presenter of the BBC's technology show *Click*

How to... PROTECT YOUR TECH

Knocks and scratches aren't good for gadgets. At best, they reduce resale value; at worst, they'll stop your kit working altogether. Here's how to minimise the impact of impacts

SHOCKS

Rubber or plastic bumpers for your phone will take the edge off an impact, and give the sensitive electronics a fighting chance. If you want a bespoke set of shock absorbers, you could try buying some Sugru. Mould it into whatever shape you want and stick it to your device (for example, corner bumpers for your phone), and it will 'set' within 24 hours. By then the Sugru will still be rubbery enough to soften most blows.

SHELLS

A carry case for any device is a great idea, and if it's one with shock-absorbing properties, even better. D3O is a flexible material that distributes the energy of the impact throughout a case's structure. If there's a chance your kit could get wet, then use a bag with a water-resistant or waterproof zip, or even better, a roll-top dry bag. Small devices can be kept in a wide-necked screw-top bottle.

SHIELDS

Screen protectors for smartphones are a wise investment, guarding against scratches and greasy fingerprints. Look for protectors that don't reduce the screen's sensitivity. Similar protectors are available for compact camera screens. If you have a DSLR, you'll know that the lens is pretty valuable, so screw on a UV filter – a clear cap that sits in front of your lens. They're much cheaper to replace should the worst happen.

Tech Doc's app prescription

WAZE

iOS, Android, BlackBerry, Nokia Free

Waze is community-powered sat-nav – a great idea that gets better as more people get involved. As well as providing turn-by-turn instructions, users' movements are shared to build up a picture of traffic. Users can also share info on roadblocks, incidents and dangerous roads so you're never surprised.

AURASMA LITE

iOS, Android Free

This augmented-reality app lets you place virtual images in the real world. Take a picture of a building or an object, and then decide what picture or animation you'd like to see there. When you or anyone else then views it through the app, your contribution will appear over the real-world object.

ALAMY

With his trusty pickaxe, Pablo set out to carve a name for himself in the world of cubism

MINECRAFT

PC, Mac
Mojang, £16.95

At first glance, *Minecraft* is an unlikely success. With neither fancy graphics nor obvious objectives, it has little in common with the high-profile hits crowding the sales charts. But it's already made its mark, with four million copies sold before it was even deemed finished by the small team that developed it over two years of public testing.

A success it may be but, with its lack of prescribed goals, *Minecraft* isn't exactly what you'd call a game. At least, not in the strictest sense. *Minecraft* is more of a blocky construction kit that makes up a shared world in which players do whatever they see fit. Think of it like a sandpit in which you play, but instead of building sandcastles you build your entire environment.

You begin with just your avatar and a few minutes to prepare for night, when dangerous monsters roam. Hollow out a dirt cave with your bare, blocky hands and the excavated cubes of earth drop into your inventory. Place a few cubes in the doorway and you're safe. This is how you learn the essence of *Minecraft* (dig, gather and build).

There's a sophisticated system for combining and crafting mined materials, as well as villages and dungeons to discover, and even a hellish alternate dimension to explore. But as fun as all that is, what's unique about *Minecraft* is the thrill of combining lavish construction with risky adventuring, giving you the freedom to play exactly as you please. ●●●●●

Get carried away with boundary disputes and all your neighbours disappear

ALSO OUT

ELDER SCROLLS V: SKYRIM

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Bethesda
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Skyrim does fantasy escapism and full-blooded immersion on a breathtaking scale. You play an adventurer discovering your destiny in Skyrim, a vast, beautiful, frost-covered land that's teeming with life. Against a backdrop of civil war and dragon attacks, the people of Skyrim have stories of their own and woes aplenty, and it's just as easy to lose yourself in these as to battle your way through various quests. ●●●●●

THEME PARK

iOS
EA
Free

Theme Park looks and sounds cute but is more like a collection of simple mini-games with strategy trimmings rather than the cheeky amusement park-building simulator of old. You play by tinkering with your rides to earn extra cash. The app's initially free but it puts on the hard sell at every turn, pushing you to buy time-saving 'super tickets' to speed up your park's progress. A disappointing mobile reworking of the classic PC simulator. ●●○○○

Jane Douglas

In with the new?

Like everyone, gamers are facing tough financial times. So when prominent game developers like Ken Levine, creator of *BioShock*, say there's plenty of power still to be squeezed from current consoles, the need for new hardware seems less than pressing.

And yet, the next generation is already on the horizon. According to Julien Merceron, technology director of games publisher Square Enix, current machines will see improved graphical performance over the next two to three years. But he also thinks improvements will start to diminish in about 18 months because "the talent is moving on to something else."

For Nintendo, that "something else" is the Wii's successor: the Wii U. And while Microsoft and Sony's plans are still under wraps, there are rumours of imminent unveilings and developers tinkering with exciting new tech.

Nintendo's Wii U will take over from the Wii… gradually

But it may not mean turning our backs on the current crop just yet. It's possible we'll see a sizeable overlap in generations, with current and next-gen consoles peacefully co-existing like the PS3 and the PS2. The latter has sold over 150 million units, and new PS2 games are still being released a year after its intended 10-year lifespan.

Sony recently debuted the Move to revitalise the PS3 with motion control, while Microsoft hopes its Kinect system will keep the Xbox 360 going for another five years. Between these add-ons (in which the manufacturers have invested heavily) and the juice still to be squeezed from existing machines, expect to see current consoles sticking around for a while yet. But the next generation is already breathing down their necks.

Jane Douglas is section editor of GameSpot UK

Bill Thompson

How social should TV be?

I don't watch much live television because I rarely manage to organise my life well enough to sit down in front of the telly while a programme is being broadcast. When I do watch TV, it tends to be through a catch-up service like iPlayer or 4OD. But now that I've got the Zeebox app on my iPad, I might just find myself watching more live broadcasts. Calling itself a 'TV sidekick', the app knows the programming schedule and keeps track of what you and your friends are watching. It also uses tools such as Twitter so you can chat and tweet about programmes, as well as letting you invite your mates to watch the same show.

Connecting television viewing to online social networks is an obvious thing to do, and Zeebox isn't alone. Boxee does something similar, and even Facebook offers the opportunity to listen to, or watch, whatever your friends are currently enjoying as you hang out with them online.

All of these services are trying to make watching TV a more social experience. The idea behind them is to expand the range of people you can talk to about a show, extending the group discussion beyond your friends, colleagues and family at home. These services put the programme at the centre of the online interaction, rather than chatting about something that just happens to be taking place on a TV screen.

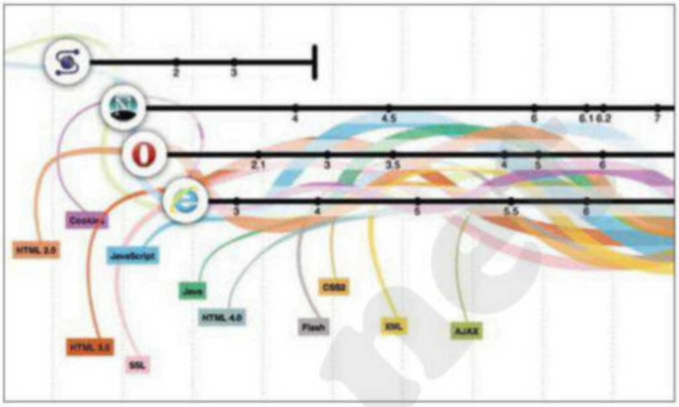
Social TV raises two questions. First, do we want this sort of sharing to happen at all? After all, the point of TV (for most of us) is to turn on, tune in and zone out. If it's hard enough to cope with the kids talking while you're trying to watch something, surely a constant stream of Twitter messages is just going to be annoying. But for live sporting events, reality TV and competition shows with audience voting like *The X Factor* or *Strictly Come Dancing*, the integration could add real value. It would provide a single online space for every programme, instead of separate websites or apps for each show.

The second question over social TV could be a big issue for the broadcasters. One reason I might watch live television is that my friends are seeing it at the same time too, but with Zeebox I can suggest that we synchronise our catch-up watching. So social viewing via the internet could easily make the TV schedule even less relevant to your daily life.

Bill Thompson contributes to news.bbc.co.uk and the BBC World Service

The Evolution Of The Web

evolutionofweb.appspot.com



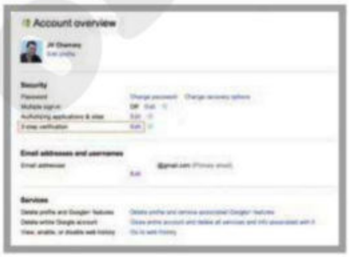
The thing we call the World Wide Web started off as a simple way of publishing hypertext documents on the internet. But over the last 20 years, it has become an extensive and complex ecosystem of technologies, languages and protocols that together offer users rich browser-based interactivity and access to a vast range of online resources.

This beautifully designed timeline illustrates and documents the web's evolution from 1990 onwards. It offers a clear visualisation of what each new development delivered. With clear and smooth navigation, pop-up windows provide detailed information on browsers (including their version history and screenshots of old versions) and the technologies and standards that create the web.

The background looks like a multicoloured river delta, with tributaries flowing into the ocean of HTML5, the latest standard – mouse over one tributary and you can see how it has developed. A great resource for anyone who wants to know more about where the web came from.

WEB HACKS

Add extra security to your Google account with 2-step verification



What? Services such as online banking often use two-factor authentication to provide more secure access to your account. This involves presenting two different pieces of evidence to prove you're the account holder, your PIN plus a code generated by a key fob, for example. It's now been rechristened as '2-step verification' and made available for Google accounts. As well as typing your current password, you also enter a new second passcode, sent to your mobile as a text message or via the Google Authenticator app on your smartphone.

Why? Since people now use Google for everything from email to document storage, it makes sense to add an extra layer of security. You can also authenticate a computer or an app so you only need your normal password most of the time.

How? Login to Google and go to 'Account Settings' (top right). Select 'Edit' next to '2-step verification' under 'Account overview', then follow the steps to add or verify your phone number using the code in the SMS sent to your mobile.

STEM eLibrary

http://j.mp/STEMeLib

The UK National STEM Centre offers support to teachers of STEM subjects (science, technology, engineering and medicine). Its multimedia eLibrary has an excellent collection of online resources on a wide range of topics. There's also a decent events calendar as well as a good community section where you can make your own resource lists, review material and create or take part in discussion groups.

Living Books About Life

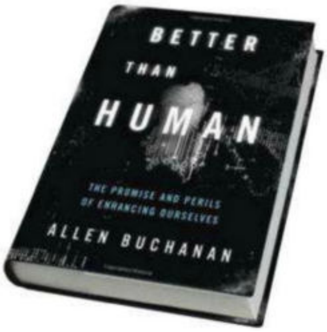
www.livingbooksaboutlife.org

This brave experiment sees the Open Humanities Press publish a series of books about life that address both biological and philosophical questions. Covering areas like bioethics, cosmetic surgery and electronic waste, each book is an editable wiki that can be amended and commented on. The navigation takes some getting used to, but there's a lot of interesting material to delve into.

WorldMags.net

Better Than Human

Strong on the ethics of human enhancement but not new technology, says **Kevin Warwick**



The Promise And Perils Of Enhancing Ourselves
Allen Buchanan
OUP, £12.99
(256pp, hbk)

Allen Buchanan has written widely on the topic of ethics applied to the human condition and, last year, published a more academic tome on the possibilities of human enhancement. *Better Than Human* is his new book and aimed at a general audience, cutting out what the author describes as "arcane discussions that are appropriate for scholars."

One good point about this book is the standpoint that Buchanan takes. His is a balanced approach to the pros and cons, and he deals in a succinct fashion with issues such as 'playing God' and 'moral flabbiness'. The author also doesn't fall into the trap of coming out with a blanket endorsement of all human enhancements: as he says, some will be a good idea, and some will be bad. He makes the pertinent point that we shouldn't continue to let biomedical enhancements sneak through the back door – we have choices to make.

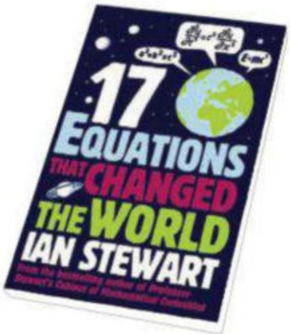
This is a thorough book, written by an ethicist for ethicists, and as a result it is technically very weak. Buchanan deals well with enhancements through drugs and gets by when dabbling with the issue of genetic modification. But where technological upgrades are concerned, such as links between brains and computers, I got the impression that he hadn't done his homework and it leaves the book with a gaping hole.

Overall, this is a mixed bag. A discussion on enhancement by biomedical means is timely and appropriate, which should ensure this book makes a neat contribution (unless your thing is arcane discussion, that is). And in terms of drug enhancements, the author does an excellent job of distilling the relevant arguments. But perhaps he needs to plug his brain into the internet to become fully aware of the actual possibilities of human enhancement. ●●●○○

Professor Kevin Warwick is a cyberneticist at the University of Reading

Genetic modification and drugs could be used to enhance humans but technology might offer us a greater potential for upgrading

GETTY



17 Equations That Changed The World
Ian Stewart
Profile, £15.99
(pbk, 288pp)

Ian Stewart is a master of mathematical exposition, and this book gives a broad overview of the way maths has been applied over the centuries. Each chapter starts with an equation, but the exposition that follows is remarkably free of any mathematical notation. Yet it's not without sophistication, dealing in detail with things like waves, electromagnetism and the famous second law of thermodynamics. An enormous historical panorama is laid out before you.

When dealing with Einstein's theory of relativity, for example, Stewart makes it clear what the theory is and isn't about (you certainly feel his irritation at people who think Einstein's relativity is the same as Newtonian relativity). He explains how Einstein's $E = mc^2$ equation comes out of special relativity before moving on to how gravity is incorporated into general relativity. This then leads him on to recent ideas about inflationary universes and dark energy. After relativity comes an excellent discussion of Schrödinger's cat followed by the applications of quantum theory and more.

This book has something for everyone interested in the applications of maths, and gives an interesting and authoritative historical perspective on a wide variety of topics. ●●●●●

***Prof Mark Ronan is a mathematician and author of* Symmetry And The Monster**

The Enigma Of The Aerofoil

Rival Theories Of Aerodynamics, 1909-1930

David Bloor

Chicago, £22.50

(608pp, pbk)

Don't ask a scientist how flight works. Chances are you'll get an explanation that sounds plausible, but is in fact baloney. The usual line is that aerofoils produce lift by making air travel faster, and thus at a lower pressure, over their top surfaces than underneath.

The trouble is this explanation rests on laws that break down under the conditions that apply to aerofoils. The shocking truth is that, while aerodynamicists know how to design effective aircraft wings, nobody can explain how they work. At least, not using words. The real explanation for flight is actually buried in a mind-bendingly complex formula called the Navier-Stokes equation.

So how did the science of flight ever get off the ground? That's the story David Bloor tells in this book, and the result is an engrossing study of how scientists deal with 'explaining' the ineffable. Around a century ago, British experts came up with a more realistic theory of flight, only to find it gave unreliable results. Meanwhile, German experts adopted 'fixes' that gave them the right answers using the simple-but-wrong theory. And it's still used today, which will worry those who prefer to fly using explicable physics.

Bloor's exploration of the sociology behind the science of flight is demanding, but well worth the effort. ●●●●○

Robert Matthews is visiting reader in science at Aston University

Expert Bookshelf

Physics

Chosen by **Andrew Steane**

QED: The Strange Theory Of Light And Matter

Richard Feynman (1985)

Penguin, £9.99

This book is about the way light [photons] move around and interact. Quantum physics presentations say a photon is in two places at once, which isn't wrong but doesn't help you understand what it means. Feynman's book conveys the essence of the idea without sophisticated maths, and makes you feel you've got a good sense of what's going on.

Genius: Richard Feynman And Modern Physics

James Gleick (1992)

Abacus, £14.99

Feynman was one of the remarkable people of 20th-century physics. His intuition was very powerful: he found methods, mathematically, of doing what others could only do in more complicated ways. He was a lively character with quirky anecdotal stories. This biography shows the fun side of Feynman, but also the seriousness of the man, and that some of his stories should be taken with a pinch of salt. When you read the reality, it's just as interesting.

The Flying Circus Of Physics: With Answers

Jearl Walker (2006)

Wiley, available online

This isn't quite a puzzle book, but it presents scenarios involving physics and you have to try to figure out what forces and effects are at work. For example, when you point a searchlight into the sky, like in *Batman* films, why would you see a distinct symbol projected against the clouds? Wouldn't it be all spread out and blurred? A great book for teenagers who are interested in physics.

***Prof Andrew Steane is the author of* The Wonderful World of Relativity**

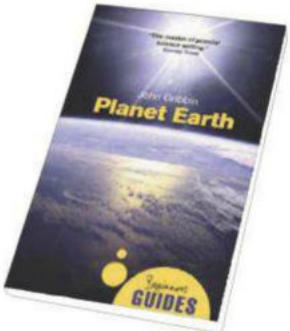
Planet Earth

A Beginner's Guide

John Gribbin

Oneworld, £9.99

(186pp, pbk)



There are delightful echoes of Douglas Adams in John and Mary Gribbin's new book. In the very first paragraph they point out that our home is a ball of rock, covered with a thin smear of water and gas, orbiting a star we call the Sun.

You're in very safe hands with these veteran science writers, as they lucidly explain all the features of the restlessly dynamic, vibrant and living planet. From the polar ices to the fires deep within, this is an excellent introduction to our homeworld. ●●●●●

Dr Lewis Dartnell is an astrobiologist at University College London

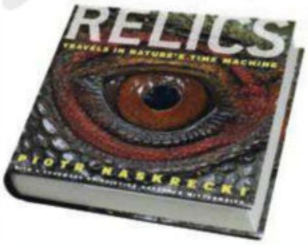
Relics

Travels In Nature's Time Machine

Piotr Naskrecki

Chicago, £20.99

(384pp, hbk)



A book like this one doesn't come along very often – it is quite simply breathtaking. Naskrecki takes you on an astonishing journey to far-flung corners of the globe to meet fabulous creatures that time forgot.

Beautifully written and laden with stunning images, this magnificent book is both an inspiration and a powerful reminder of what we stand to lose if we're not careful. Devour this book in one life-affirming go, or savour it chapter by chapter. Just don't leave it lying around – someone will walk off with it. ●●●●●

Dr George McGavin is a zoologist and BBC TV presenter

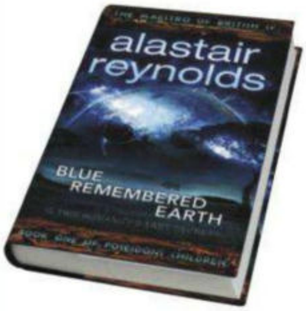
FICTION

Blue Remembered Earth

Alastair Reynolds

Gollancz, £14.99/£18.99

(448pp, pbk/hbk)



We're living through interesting times, when you might expect dystopian science-fiction to be the order of the day. Not for British author Alastair Reynolds, whose 'Poseidon's Children' trilogy kicks off 150 years hence. Climate change has bitten, but we're coping – even thriving – as we colonise the Solar System. Against this backdrop, Reynolds spins a tale involving the mega-rich Akinya family living in a technologically advanced Africa and a discovery that will change humanity's future. It's a brilliantly realised argument for optimism. ●●●●○

Jonathan Wright is a writer and science-fiction fanatic

WorldMags.net

THE TO-DO LIST

The essential guide to the month ahead

1

FEB

EDITOR'S CHOICE

Brighton Science Festival

The theme of this event-packed festival is 'the big shake up'. First, shake up your mind and ponder whether your understanding of the world is anything like what actually exists. Subjects range from the quantum world, to consciousness and religion.

Next up, investigate the catastrophes that shake up our worlds. Find out more about droughts, pandemics, flooding, famine, global warming and the economic meltdown – and how we can avoid them.

Finally, shake up your creative juices and learn how to think of new ideas without getting hung up on the old ones. There will be performances by comedians Robin Ince and Marcus Brigstocke, as well as events with scientists such as Rupert Sheldrake. Family fun days are on 11-12 February; the Big Science Weekend is 25-26 February.

1 February – 7 March.
www.brightonscience.com

13 FEB

SPEAKER OF THE MONTH

Dr Brad Amos

Who is he?

A fellow of the Royal Society, Dr Brad Amos is an Emeritus Research Group Leader in the MRC Lab of Molecular Biology in Cambridge and a Visiting Scientist at the University of Strathclyde.

What does he research?

Together with his colleagues, Amos developed the biological laser-scanning confocal microscope, which helps researchers construct 3D images of cellular tissues.

What's he talking about?

How microscopy is being transformed by cutting-edge tech, such as lasers and computers and the latest techniques he's developing.

Royal Society, London, 13 February, 6:30pm Free, no advance booking required, doors open at 5.45pm, http://j.mp/OpticalMicroscope

14

FEB

Valentine's Day Special: Evening With The Stars

Tired of gazing into each other's eyes on Valentine's night? Instead, why not gaze at the stars through an enormous 28in telescope, before cosying up for a planetarium show? And to ensure there's something for the romantic types, each couple attending receives a red rose.

Royal Observatory, London, 14 February, adults only, £28 (booking advised), 020 8312 6608, www.rmg.co.uk/visit/events/ews-valentines-day

27

FEB

What's Left To Explore In Our Solar System?

It seems like every day another exoplanet is found. Will we soon have discovered all there is to find, given our current technology? No, says Imperial College astrobiologist Dr Zita Martins, whose job it is to hunt for organic matter in meteorites. Join her at this Café Scientifique event on a guided tour through unexplored parts of our Solar System.

The Royal Society, London, 27 February, 6.30-8pm
Free, http://royalsociety.org/events/2012/explore-solar-system

THE MEDICAL RESEARCH COUNCIL, OXFORDSHIRE SCIENCE FESTIVAL, SCIENCE PHOTO LIBRARY, NASA, BBC

1 MARCH

The Ring Of Fire

More than 75 per cent of the world's volcanoes sit on the Pacific Rim, and 90 per cent of earthquakes occur around it. Find out why, and how earthquakes and underwater eruptions can kick-start tsunamis. **Natural History Museum, Attenborough Studio, London, 1 March, 2.30pm; 3 March, 12.30pm and 2.30pm. Free, www.nhm.ac.uk/nature-live**

3 MARCH

Science In Your World

To open the Oxfordshire Science Festival (3-18 March), this event in Oxford's central shopping district has 20 stalls with hands-on activities showing how science impacts on your everyday life. Learn how to extract DNA, or explore urban pond life and play around with levitating magnets. **Oxford, 3 March, 10am-4pm, www.oxfordshiresciencefestival.co.uk**

5 MARCH

Small Is Beautiful

Cute, furry mammals often steal the limelight from plants, but our leafy green friends are crucial to our survival. That includes tiny mosses, liverworts and hornworts known as 'bryophytes'. Discover why they're so vital and where to look for them. **Natural History Museum, Attenborough Studio, London, 5 March, 2.30pm. Free, www.nhm.ac.uk/nature-live**

5 MARCH

Stormy Weather: The Meteorology Of Cocktails

We Brits are obsessed with the weather… and alcohol. Join Noel Jackson, the Newcastle Centre for Life's Head of Education and resident cocktail mixologist for an evening of meteorological facts, amusing anecdotes and weather-themed cocktails. Sip your way through the evening with a Hurricane or a Sea Breeze – just don't forget to ask for an umbrella. **Centre for Life, Newcastle 9 March, 7-11:30pm £25 (price includes five cocktails and a buffet). www.life.org.uk/whats-on**

15 MARCH

AfterLife: Secrets And Lies

Is it possible to protect our secrets in an online world? What are others hiding from us? While banks can develop advanced encryption systems to protect their money, what can we do to protect our identity online? In this age of texting and tweeting, who can we trust and can we really hide information online? **Centre for Life, Newcastle, 15 March, 7-10pm, £4, http://j.mp/LiesSecrets**

TV & RADIO

The month's top science programmes

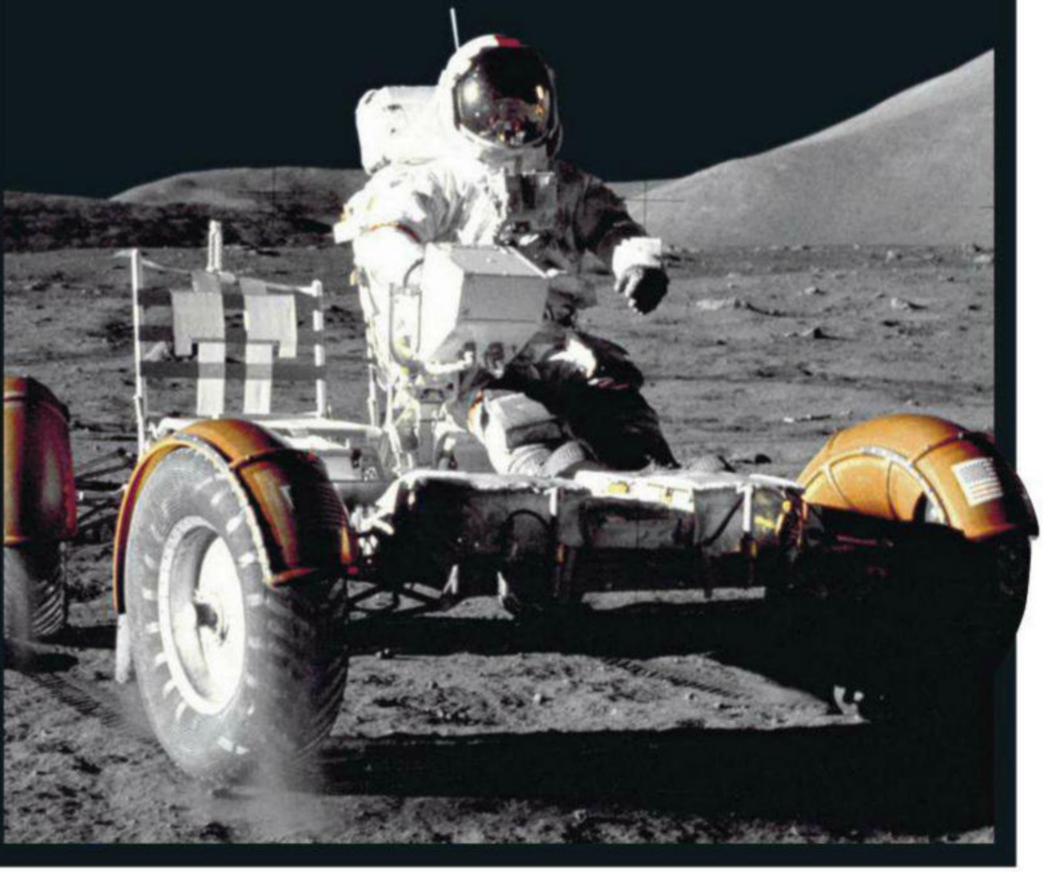
Apollo 17: The Untold Story Of The Last Men On The Moon

Quest
16 February, 9pm

NASA's Apollo programme sent the first human beings to another world in 1969, but in 1972 it was cut short. Apollo 17 left the Moon on 14 December 40 years ago and was the last mission to leave a human footprint behind. The crew of that final lunar mission were Eugene Cernan, Harrison Schmitt and Ronald Evans.

Schmitt was a geologist and the only scientist NASA sent to the Moon – and for good reason, as Apollo 17 was a science mission. Its objective: to take samples from the lunar surface, photograph craters and bring back material that might help in studying the history of the Moon and its formation. This programme will outline the science that's still being done with the samples returned aboard Apollo 17.

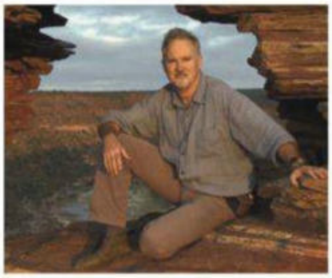
But there are other stories too, like the first Moon Rover crash and the thousands of other people who made the Apollo missions happen. For them, Apollo 17 was the culmination of the most ambitious space programme ever achieved. Hankies at the ready, space fans.



Untold stories include the first Moon Rover crash

Australia: Time Traveller's Guide

Eden
Starts 27 March, 8pm



A trip around Australia is a journey back in time, to the formation of the oldest rocks still in existence. This four-part series, filmed in HD, begins with Pre-Cambrian rocks in Western Australia, formed back when the Earth's crust was fresh.

The history of the continent – how it joined the supercontinent Gondwana and suffered bombardment from space before its eventual separation from Antarctica – is only half the story. As the land rose and fell and moved around the globe, life was also evolving. Plants pumped oxygen into the atmosphere, complex animals followed and then whole branches of life evolved that were uniquely adapted to Australia.

The Secrets Of Everything

BBC Three
March (TBC)

Scientist and adrenaline-junkie Greg Foot tackled some big questions in *Secrets Of The Universe*, and now he's back with more questions that need answering in this new six-part series. Questions such as "Can a belly flop kill me?" and "If enough people jumped at the same time, would the Earth really move?"

Wherever possible, Foot sets out to physically throw himself – and other volunteers – into answering them. He tries getting 50,000 Reading Festival-goers to jump at the same time to challenge the Richter Scale, and gets his fingers hammered to find out if swearing really does work as pain relief. He doesn't test the belly flop theory in person, though.

NASA, THINKSTOCK X3, NATIONAL GEOGRAPHIC CHANNEL X3, BBC X2, EDEN

Radio

Where Do Flies Go In Winter?

BBC Radio 4
26 February, 6.35am

Not the most glamorous episode of *Living World*, but surely one of the most intriguing. From the first annoying gnat dancing in the spring sunshine to the last bothersome bluebottle bumping against the window in autumn, flies are warm-weather creatures. So where do they go in the winter? Hibernation? A villa in Spain? Miranda Krestovnikoff goes looking for cluster flies in the attic.

The Human Race And The Global Body

BBC World Service
Starts 5 March, 4.30am

Genetically, the human race is surprisingly homogenous, but some differences reflect millennia of evolution to adapt to widely varied environments. This four-part special in the *Discovery* series explores how our movement around the globe has shaped our bodies, and how moving to different climates can affect our health. Finally, it asks how our unprecedented mobility and urban lifestyle could affect our future health. (Repeated later for those not up at 4.30am.)

Doctor – Tell Me The Truth

BBC Radio 4
Starts 20 February, 8pm

We like our doctors to be human, but we don't like them to be fallible. They mustn't be like robots, but they must never get anything wrong. In fact, patient is the last thing patients are. Surgeon, author and *New Yorker* writer Atul Gawande tackles the idea of perfection in medicine. When things do go wrong, is honesty the best policy? Gawande interviews doctors who have decided to admit when they make mistakes.

Squeamish

DMAX
Starts 14 Feb, 10pm

After years of pretending it's only kids who are fascinated by snot, pus and poo, finally a series for adults on things that will make you go "Eeeww!"

Squeamish gives us the science involved in analysing the bacteria in faeces, but the stories of a man who collects toenail clippings and a boy who can skip through his own arms will be just as engrossing. Just finish your dinner first.

Lost World Of The Pacific

National Geographic
22 February, 9pm

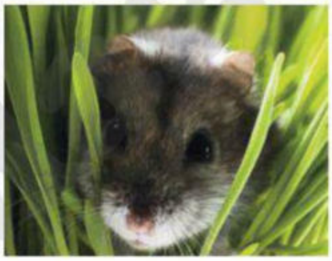
Just as mythical Atlantis was said to have sunk into the Atlantic Ocean, the Pacific has legends of the lost continent of Hiva.

The Easter Islanders claim to have descended from refugees who fled Hiva, which disappeared after a disaster. Now archaeologists, geologists and linguists investigate an exciting theory: that the Polynesian Marquesas Archipelago is all that remains of this long-lost land.

Great Animal Escapes

Animal Planet
Starts 16 Feb, 8pm

Dogs that master door handles, cats that don't need catflaps and gerbils with tunnelling skills worthy of *The Great Escape*: we've all known pets that can't be cooped up. But a bull that seems headed for a china shop? Elephants out for a suburban stroll at midnight? Are animals really that smart? In this series, behavioural experts try to explain what's going on when animals keep breaking out.



Hunt For The Giant Squid

Nat Geo Wild
27 February, 8pm

Giant squid can't survive in the water pressure near the surface of the seas and so they spend their entire lives hundreds of metres below sea level.

In order to see one alive, filmmaker Martin Dohrn and his team will have to go looking in its home territory, which sunlight can't reach. Armed with night-vision cameras on a custom-built stealth rig, the team head to the Azores in the hope of spotting, and filming, a living 12-metre long cephalopod.

Big Cat Week

Nat Geo Wild
Starts 19 February

Forget the cold outside, turn up the central heating, lie back and imagine you're one of a pride of lions on the Serengeti. Every night you can see a different big cat story, from hand-rearing leopard cubs to watching inter-species rivalries or looking at technology used to film the elusive jaguar in the jungles of Central America. Don't blame us if your moggy starts getting delusions of grandeur.

Madagascar

Eden
Starts 6 March, 8pm

Not the animated movie but a three-part, BBC-made programme narrated by David Attenborough. Like the Galapagos, Madagascar's isolation has made it the site of a wonderful evolutionary experiment, with more diversity even than the islands that inspired Darwin. It's so inaccessible, few film crews have explored the varied landscapes of the world's fourth-largest island: mountains, deserts and rainforests, each with unique wildlife.

BRAINTRAINING

Pit your wits against these brainteasers by **David J Bodycombe**, question-setter for BBC Four's *Only Connect*

Win Haynes **Millennium Falcon** Manuals

Prize Puzzle

What do the following letters all have in common?

C O S V W X Z

The first five correct entries drawn from the *Focus* hat will each win a copy of the *Haynes Millennium Falcon Owner's Workshop Manual*. Send your entry, marked 'Prize Puzzle 239', to the address on p109 by 8 March. We regret we cannot accept email entries.

See ***sciencefocus.com/winners*** for previous winners and solutions

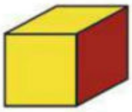
Correction The Prize Puzzle featured in the December issue of *Focus* (no 236) contained an error that made it almost impossible to solve. Please accept our apologies for this. Nonetheless, Peter Hayworth (Bristol) and Duncan Field (Romsey) managed to figure out the correct answer and each win a Maglite XL200 torch. The remaining prizes from December will be offered again in a future issue.

QUESTION 1

On which day of the year do the fewest people die?

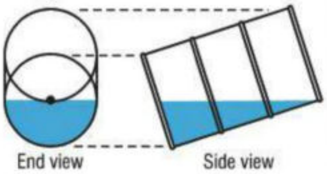
QUESTION 2

How many different ways can you paint the faces of a cube with red and/or yellow? (Cubes that differ only by a rotation are considered identical.)



QUESTION 3

Is the volume of liquid: exactly a quarter of the overall barrel, a little more, or a little less?



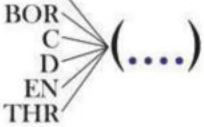
QUESTION 4

What letter and number is missing from the empty column?

G	G	G	G	W		E	G	E
1	2	3	4	4		7	5	8

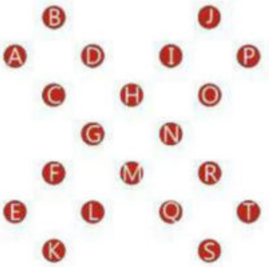
QUESTION 5

Which four letters go in the brackets to form six new words, none of which rhyme with any of the others?



QUESTION 6

How many squares can be drawn such that each corner coincides with one of the dots in this diagram?

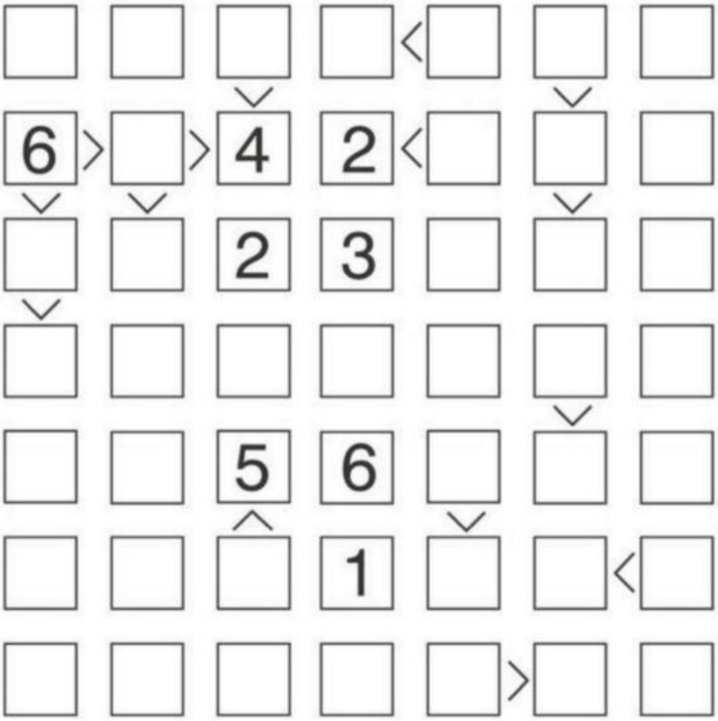


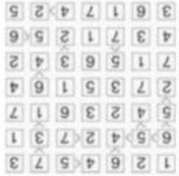
QUESTION 7

Once, a US cable company broadcast an advert offering a free T-shirt for viewers during a high-profile boxing match. Why did they deliberately scramble the signal so that even pay-per-view subscribers couldn't see the offer?

QUESTION 8

In the puzzle below, called a Futoshiki, each row and column must contain all the digits from 1 to 7. Also, all the less than/greater than signs must be obeyed, for example 4 < 5 or 7 > 2. Can you complete the grid?





1	2	6	4	5	7	3
6	5	4	2	7	3	1
5	4	2	3	6	1	7
2	7	3	5	1	6	4
7	1	5	6	3	4	2
4	3	7	1	2	5	6
3	6	1	7	4	2	5

Solutions

Q1) On the same day that the fewest people are born – 29 February. **Q2)** 10 ways. **Q3)** Less than a quarter. Though the side view implies that it is one quarter full, the liquid is in the narrower parts of the barrel where the liquid level is most shallow. **Q4)** 'V' for Victoria. They are the initials and regnal numbers of UK rulers from George I to Elizabeth II. **Q5)** OUGH, to form BOUGH, BOROUGH, COUGH etc. **Q6)** 21 in total – 9 like A-B-D-C, 4 like C-H-M-F, 2 like C-I-R-L, 4 like A-I-Q-E and the two largest: B-P-S-E and A-J-T-K. **Q7)** To clamp down on piracy. The people who rang for the T-shirt were likely to have illegal decoders, since legitimate customers couldn't see the advert. (Time Warner caught 400 people this way in 1993.) **Q8)** See illustration.

Quick Quiz

Test your knowledge of space rocks

QUESTION 1

What term refers to the area where meteorites from a single fall land?

a) Strewn field
b) Debris patch
c) Fragmentation footprint

QUESTION 2

Which of these is not a meteor shower?

a) June Bootids
b) Pi Puppids
c) Murdam Usorrids

QUESTION 3

What is the point from which a meteor shower appears to originate called?

a) Radiant
b) Antecedent
c) Provenient

QUESTION 4

When was the Chicxulub Impact, thought to be responsible for killing the dinosaurs?

a) 55 million years ago
b) 65 million years ago
c) 75 million years ago

QUESTION 5

Roughly how heavy is the Hoba meteorite, the largest ever found?

a) 60kg
b) 600kg
c) 60,000kg

QUESTION 6

When was the first documented case of a person being struck by a meteorite?

a) 1554
b) 1754
c) 1954

QUESTION 7

Where is Lake Siljan, Europe's largest meteorite crater?

a) Sweden
b) Croatia
c) Hungary

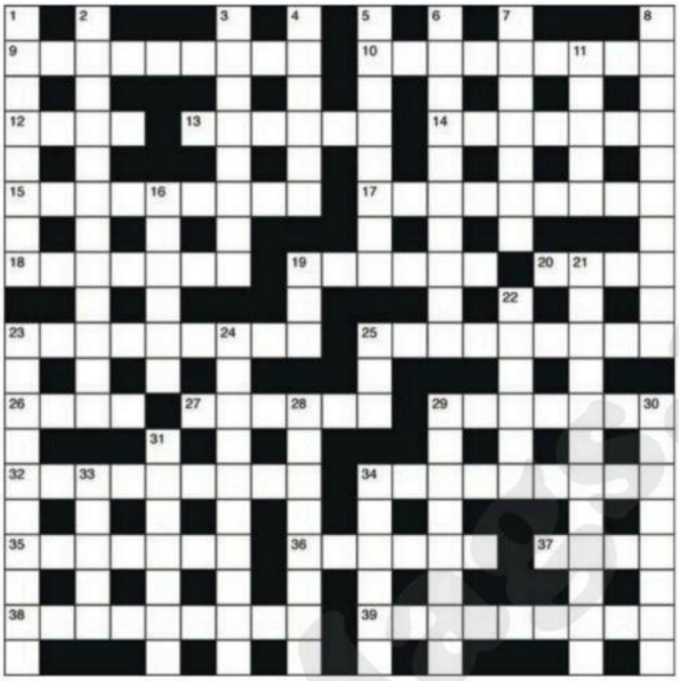
YOU ARE:

0-2 Sailing through space
3-5 Burning up in the atmosphere
6-7 Making an impact

Answers: 1a, 2c, 3a, 4b, 5c, 6c, 7a

EVERY MONTH, A NEW CHALLENGE SET BY **AGENT STARLING**

Focus **crossword** *Nº 138*



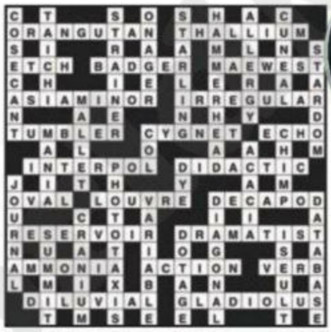
Across

9 Heard yours truly hit something – top hole! (3,6)
10 Quietly simmer, then put on fruit (9)
12 Bath has a fair bit of brass (4)
13 Unexpected result in Northern Ireland (6)
14 Turning blue if having only green energy source (7)
15 Press stage performance at gorge in the Danube (4,5)
17 Delivery of an emperor (9)
18 See nothing in new dragon moulding (7)
19 Plan to fuse to an embryo (6)
20 Sharp as a group of detectives (4)
23 Charming location for a strike (5,4)
25 Capacity, on occasion, for four dimensions (5-4)
26 Hatchet left inside bar (4)
27 Come round, having to behold body cavity (6)
29 Group of spices used round the East (7)
32 Insect, say, makes Thor drop a clanger (9)
34 Warns fop about taking German eggs (9)
35 Attractive object on old generator (7)
36 Seafood is delivered round some tents (6)
37 Must deal with filth (4)
38 Volunteers shout to university student, 'a spider!' (9)
39 Rod in shop, ordering red pigment (9)

Down

1 Progressive part of the house (4,4)
2 Gas transporter gets socialist family to join group (3,5,4)
3 Leeks not using a supporting structure (8)
4 Figures about union ranking (6)
5 Clips are about respiratory aperture (8)
6 Blue car ban affected heavenly object (4,6)
7 Concentrating on two things at once (7)
8 Deny a line about having one colouring (7,3)
11 Time to employ a computing accessory (5)
16 Got it altered by old painter (6)
19 Chef attempts to include adipose tissue (3)
21 Important Sam's ordered enough to sustain fission (8,4)
22 Vacation in an alcove (6)
23 POW camp has a little bit of calcium formation (10)
24 Shop around twice with rugby element (10)
25 Total or just part, we hear (3)
28 Real dots used to make a point of reference (8)
29 Deadly creature caught, only during prison break (8)
30 Star with weight of a feldspar (8)
31 Gold inclines towards French city (7)
33 Row about key animal (5)
34 Shoot, taking account of horse-drawn vehicle (6)

Solution to Nº 135



The first five correctly completed crosswords drawn from the *Focus* hat will each win a copy of *Future Science*. Send your entry, marked 'Crossword 138', to the address below by 8 March.

Congratulations to Sheila Smeal (Edinburgh) who correctly completed Crossword no 135 in the December issue and wins an Apollo Command Module model from Revell.

YOUR DETAILS

NAME:

ADDRESS:

POSTCODE: **TEL:**

EMAIL:

Send your entry to *Focus* at the address below. Entrants must supply to Immediate Media Company Ltd their full name, postal address and daytime telephone number. Immediate Media Company, publisher of *Focus*, may contact you with details of our products and services or to undertake research. Please write 'Do Not Contact' if you prefer not to receive such information by post or phone. Please write your email address on your entry if you prefer to receive such information by email.

Send your Prize Puzzle and Crossword entries to:

***Focus* magazine**, Tower House, Fairfax Street, Bristol, BS1 3BN

Science Festivals Guide 2012

Your pick of the very best science festivals across the UK for 2012

Brighton Science Festival 2012

1 – 29 February

We'll be shaken to the core by the oldest and the latest ideas: quantum, consciousness, religion. Shaking with fright, since Catastrophe (the BIG shake-up) is one of our themes. Shaking with laughter, as Robin Ince, Marcus Brigstocke, The Festival of the Spoken Nerd and Helen Keen take science to a new place: comedy. And shaking with excitement, when the Family Fun Weekend (Feb 11-12) kicks off half term in style.
More science than you can shake a stick at.

www.brightonscience.com
Tel: 01273 777628

Discover

8 – 10 March

Discover is a free exhibition for all ages from the University of Bristol, giving a whistle-stop tour of current and innovative research. There are all sorts of ways to get involved, from looking at new discoveries to taking part in real experiments. Dig up a dinosaur, piece together the secrets hidden in ancient fossils, interpret the wartime messages carved into ancient trees, visit the world of atoms by building a giant molecule and much more.
Free entry – The Galleries shopping centre, Broadmead, Bristol, BS1 3XD.

www.bristol.ac.uk/events
Tel: 0117 3318318

Edinburgh International Science Festival

30 Mar – 15 April

2012 sees Edinburgh International Science Festival deliver a vibrant programme that celebrates ideas and embraces discovery, innovation and creativity in all walks of life. For families there's the chance to get hands-on with a wide range of interactive exhibits and workshops in some of Edinburgh's best-loved attractions. For those looking for a night out with a difference, don't miss our after-hours events as we bring science and scientists out of the lab to create all sorts of new and unexpected experiences.

www.sciencefestival.co.uk
Tel: 0844 557 2686

The Times Cheltenham Science Festival

12 – 17 June

Times Cheltenham Science Festival welcomes hundreds of the world's greatest thinkers to the town for six jam-packed days of debate, discovery, experiments, and enjoyment. The festival theme of Re:Generation will inspire some pretty big questions as energy, medicine, technology, health and the future of society all come under the microscope. The full line-up of speakers will soon be announced, but you can look forward to Cheltenham's trademark mix of outstanding scientists, popular faces and comedy geniuses joining the debate.

www.cheltenhamfestivals.com
Tel: 01242 505 444

Energise your mind this September

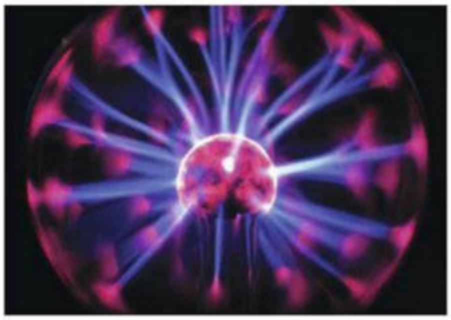
The Royal Society
summer science exhibition
3 – 8 July 2012

The Royal Society Summer Science Exhibition 3 - 8 July

Science live at the Royal Society Summer Science Exhibition. With over 20 fascinating interactive exhibits you can try your hand at the science changing our world and question the scientists themselves about the exciting advances they are working on, from tracking storms to the science of laughter. Also featuring a host of free events and activities.

royalsociety.org/sciencelive
Tel: 0207 451 2244

THE ROYAL SOCIETY



Wrexham Science Festival 19 – 27 July

Fizzing with ideas, debates, experiments, energy, fun and interactive events the Wrexham Science Festival has something to suit young and old alike and we're only 45 minutes from Liverpool and Manchester. Whether you're looking for the latest in scientific thinking and innovation, to debate your theories with the experts, to inspire a budding young scientist or for family entertainment to kick-start the summer holidays, our free workshops, demonstrations, shows and lectures will open your eyes to the world of science.

www.wrexhamsf.com • wsf@glyndwr.ac.uk
Tel: 01978 293466

Wrexham Science Festival
Gŵyl Wyddoniaeth Wrecsam

The British Science Festival Aberdeen 4 – 9 September

The British Science Festival is back in Aberdeen after nearly 50 years. The world has fundamentally changed since then and we want to showcase the latest in science, technology and engineering. Boost your brain power with our fascinating Award Lectures, get some food for thought with our lunchtime talks, or you might just fancy experimenting with the kids for some wholesome family fun. Go on, energise your mind from 4-9 September at the British Science Festival in Aberdeen.

www.britishsciencefestival.org
Tel: 08457 807 207

british science festival
ABERDEEN
4-9 SEPT 2012

The Observatory Science Centre registered charity no. 298542

Herstmonceux Astronomy Festival 7 – 9 September

The annual Astronomy Festival at The Observatory Science Centre, Herstmonceux is packed with activities, including camping under the backdrop of the observatory domes, lectures, amateur radio demonstrations, trade stalls, family fun day, fund-raising raffles, beer tent, telescope tours, planetarium shows and viewing through some of the country's largest telescopes (weather permitting). Come and soak up the incredible atmosphere among the domes and telescopes of this fabulous historic site.

www.the-observatory.org
Tel: 01323 832731

THE Observatory SCIENCE CENTRE
AT HERSTMONCEUX

... at the British Science Festival

british science festival
ABERDEEN
4-9 SEPT 2012

Instant **genius**

The force endured by a woodpecker's head on each peck is equivalent to a deceleration force 1,000 times that of gravity

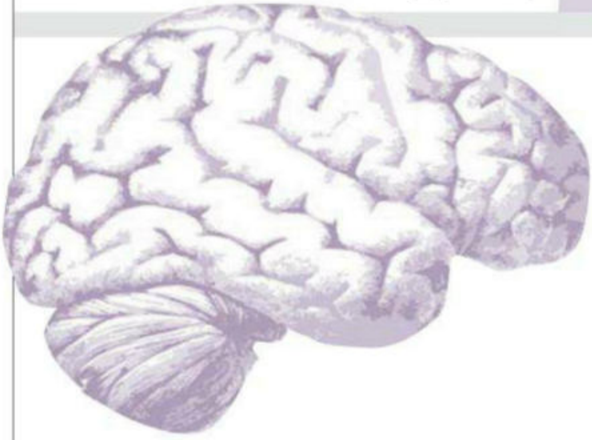
page 76

A giant gas cloud that's expected to pass within

40 billion km

of the black hole Sagittarius A by 2013 is already being distorted by the hole's gravitational pull*

page 19



Physical changes have been detected in subjects' brains after they've undertaken as little as two months' training

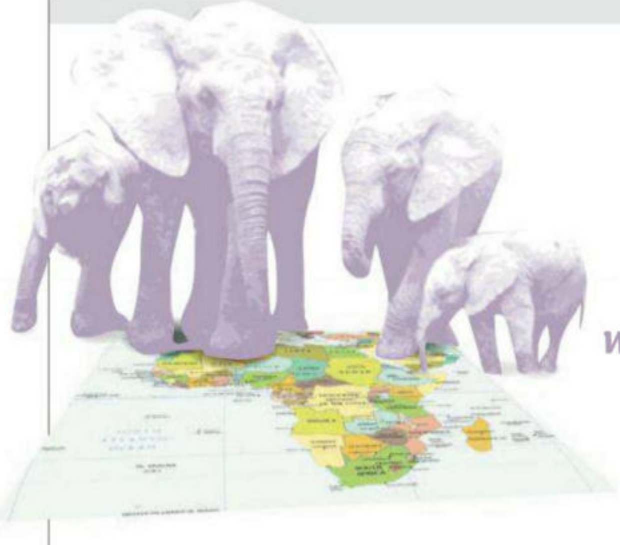
page 69

Chinese scientists have developed a way for shirts to wash themselves

page 21

Our noses may respond to the vibrations of molecules rather than their shapes. The finding could make it easier to create new perfumes

page 47



Elephants are not only able to recall places that they visited several decades ago, they also know exactly when the conditions are right to revisit these locations

page 51

To see anything on the Planck scale would require so much magnification that atoms would appear to be bigger than entire galaxies

page 39

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biOrb 105L

"For people who'd like a home aquarium, but think it's too much work"

At last, an aquarium for busy people
biOrbs have built-in lighting and simple filtration that really works. The filter cartridges are easy to change and it only takes a few seconds.

The revealing truth about aquarium filters
Many traditional aquariums have a filter on the side or at the top, but guess what - fish waste sinks. biOrbs have a filter hidden at the bottom of the aquarium. Put simply, a biOrb filter works where there is most to filter.

Why they're made from acrylic, not glass
Acrylic is ten times stronger than glass. Why's that so important? Just ask anyone who's broken a glass aquarium and flooded their home.

Did you know it's also noticeably clearer? Acrylic has a transparency rate of 93% but glass only allows 70% of light to pass through. With a biOrb it's been said that *"it's like watching fish in high definition"*.

> *"it's like watching fish in high definition"*

All you'll need to get started is included
You'll also get step-by-step instructions to help you on your way. Just sit back and enjoy the magic of keeping fish.

What's more, every biOrb is backed by our no-quibble 12 month guarantee.

NO QUIBBLE 12 MONTH GUARANTEE

There's a biOrb that's right for every home
biOrbs come in many shapes, sizes and colours. See them all at **www.reef-one.com** and choose yours today.

Inside the patented biOrb filter. Air driven filtration creates vigorous water flow. This maintains oxygen saturation. Circular water flow collects fish waste on its way down and traps it in the easy-to-change cartridge.

Ask about biOrb at your local aquatics store or buy online at **www.reef-one.com**

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